

# The influence of activated carbon annealing temperature on sunlight-driven photocatalytic dye degradation and biological activity

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## ABSTRACT

In this study, activated carbon (AC) produced from jasmine flowers was effectively manufactured using a hydrothermal carbonization procedure at various annealing temperatures. The XRD pattern revealed the graphitic phase of carbon. The surface morphology of nanoparticles exhibits uneven shapes. To investigate the photocatalytic activity of methylene blue (MB), it was photodegraded using visible light irradiation. Under solar light irradiation, the prepared activated carbon was used as a potential photo catalyst for the photocatalytic degradation of brilliant green dye, which revealed 96% degradation. The antibacterial activity of activated carbon was tested against *S. Aureus* (MTCC-737) and *E. coli* (MTCC-443) microbial pathogens, and the zone of inhibition layer was studied. To the best of our knowledge this is the first study to use jasmine flower based AC as a photocatalyst for the efficient breakdown of MB dye.

## 1. Introduction

Water is an important component of daily existence. According to the UNESCO World Water Assessment Programme (WWAP), one hundred million humans, one million seabirds, and one hundred thousand marine animals perish annually due to water pollution [1]. Industrial sludge, heavy metals, pesticides, organic dyes, and other substances greatly pollute the water supply. Humans acquire a variety of illnesses due to water contamination. Even minute amounts of dye can degrade water quality. During the colouring process, the textile and paper industries release a large amount of dye waste [2]. Methylene blue is a heterocyclic aromatic dye that appears blue when oxidised but is colourless when reduced. Methylene blue causes loss of coordination, fast heartbeat, hallucinations, fever, nausea, vomiting, and diarrhoea. The non-biodegradable colour methylene blue causes several health issues and environmental pollutions [3]. Traditional techniques cannot breakdown

methylene blue adequately. Only photocatalysis totally destroys dye without producing sludge or by-products. It is frequently used to treat coloured molecules as a result of its low cost, environmental friendliness, and absence of sludge [4]. Because of their large surface area and porosity, activated carbons (AC) are commonly used as an active material for methylene blue degradation. Activated carbon is utilised in a variety of environmental applications, including wastewater treatment, mercury removal, water purification, and gas purification, as well as energy storage, super capacitors, and batteries [5]. Corn cob, wheat straw, and rice hull in agricultural biomass-derived activated carbon [6], hazelnut shells [7], walnut shells [8], and peanut shells [9], eggshells [10], and coconut shells [11] were utilised. Activated carbon is produced using a variety of synthetic techniques, including pyrolysis, physical activation, and chemical activation. To convert carbon, the physical activation process requires high temperature and pressure. By completing the heat degradation of raw material with chemical reactions, chemical activation may be done in a single step. Chemical

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### Nomenclature

AC	Activated carbon
FT-IR	Fourier Transform Infrared Spectroscopy
H <sub>2</sub> SO <sub>4</sub>	Sulphuric acid
H <sub>3</sub> PO <sub>4</sub>	Ortho phosphoric acid
HCL	Hydrochloric acid
K <sub>2</sub> CO <sub>3</sub>	Potassium carbonate
KOH	Potassium hydroxide
MB	Methylene Blue
Na <sub>2</sub> CO <sub>3</sub>	Sodium Carbonate
NaOH	Sodium hydroxide
O <sub>2</sub>	Superoxides
OH	Hydroxyl radicals
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
XRD	X-ray Diffraction
ZnCl <sub>2</sub>	Zinc Chloride

activation operations are conducted using acidic reagents, such as ZnCl<sub>2</sub>, H<sub>3</sub>PO<sub>4</sub>, HCL, and H<sub>2</sub>SO<sub>4</sub>, or with essential reagents, such as KOH, K<sub>2</sub>CO<sub>3</sub>, and NaOH. Because they are very stable and can transfer electricity, carbonaceous materials can be used to stabilise hybrid systems and make photocatalytic energy happen.

Zhang et al., 2021 [12] stated that carbon stalk-derived hydrothermally treated activated carbon for the photodegradation of methylene blue removal obtained a 99.4% degradation efficiency at a 150 mg/L methylene blue concentration. Nizam et al., 2021 [13] described activated carbon produced from rubber seed and shell for cationic methylene blue elimination. The interaction and hydrogen bonding result in the elimination of methylene blue. Wang et al., 2020 [14] generated activated carbon by utilising phosphoric acid as the activation agent in an integrated corncob hydrothermal carbonization process. Activated carbon's surface area was measured at 480 m<sup>2</sup>/g. The ability of activated carbon to absorb dye rose from 41% to 82%. Emrooz et al., 2020 [15] created micro and mesoporous activated carbon produced from Azolla to remove methylene blue. According to this study, at the conclusion of 120 min, activated carbon mediated by jasmine flowers achieves a maximum degradation efficiency of 94%. Comparing the observed results to earlier reports. The hydrothermal carbonization method is the simplest, most ecologically friendly, time-and energy-efficient method for incorporating nanoparticles. The fundamental objective of this study is to produce a low-cost, high performance, low-temperature absorbent. Lin et al., 2021 [16]. The activator NaOH improves the surface area and photocatalytic activity of the material.

This study seeks to manufacture the catalytic activity of activated carbon by degrading methylene blue dye under UV irradiation using conventional and simple carbon. Jasmine flowers will be used as a biomaterial in an affordable hydrothermal carbonization process. In addition, the biological activities of activated carbon at various temperatures of annealing were evaluated against a variety of microorganisms that cause disease. This research covers, to the best of our knowledge, the production of activated carbon using jasmine flower extract. The annealing temperature regulated the nanoparticles' form and size.

## 2. Experimental procedure

### 2.1. Materials

All of the chemicals and reagents are utilized without being purified further. Sodium hydroxide (NaOH), Methylene blue (C<sub>16</sub>H<sub>18</sub>ClN<sub>3</sub>S), Hydrochloric acid (HCL) were purchased from Merck. Methylene blue is

a pollutant dye used for degradation.

### 2.2. Preparation of activated carbon

Jasmine flower-derived activated carbon was effectively produced by the hydrothermal carbonization method. Jasmine flower powder was added to 20 ml of distilled water together with an activating agent (NaOH) at a ratio of 4:1, followed by three hours of stirring. The solution was transferred to a 100 ml Teflon autoclave and placed in an oven at 100 degrees Celsius for three hours. To eliminate untreated biomass, the solution was cooled, filtered, and washed with distilled water and HCL. The sample was baked in an oven at 80 °C for one night, and then it was put together at different annealing temperatures (400 °C, 500 °C, 600 °C) [17].

### 2.3. Characterization techniques

A PAN analytical XPERT PRO diffractometer with Cu-K radiation (-1.54) was used to identify the structural and phase characteristics of activated carbon generated from jasmine flowers. FT-IR spectroscopy was used to analyse functional groups. The FT-IR spectra were captured using a Perkin Elmer spectrophotometer. SEM analysis was used to analyse surface morphology and particle size measurement. The Joel JSM 6390 Scanning Electron microscope was used for SEM examination. The high-resolution transmission electron microscopy was captured with the Gatan Quantum ER 965. The spectrum was acquired using Nanoplus and a particle size analyzer.

### 2.4. Photo catalytic performance of activated carbon

In the photo degradation investigation, the as-prepared photo catalyst (AC) was disseminated in 100 ml aqueous solution of MB dye. The solution was ultrasonically agitated for 30 min in a dark room before being exposed to radiation to provide the right adsorption/desorption conditions. The solution was then exposed to direct sunlight while being stirred magnetically. The reaction solution was kept at 37 °C while 5 ml of the suspension was taken every 10 min and centrifuged for 10 min at 3000 rpm. The UV-Vis spectrophotometer was then used to analyse the photodegradation behaviour [18].

### 2.5. Reactive species experiment

Reactive oxidative species entrapment studies were carried out to investigate the potential photocatalyst mechanism of MB dye over the AC. By adding 1.0 mM of disodium ethylenediamine tetra-acetic (h<sup>+</sup>), ethanol (e<sup>-</sup>), isopropyl alcohol (OH<sup>•</sup>), and benzoquinone (O<sub>2</sub><sup>-•</sup>), respectively, different types of scavengers were used in this experiment to trap photogenerated electrons, holes, hydroxyl radicals, and superoxide radicals. For the scavenger investigation, the same photocatalytic experimental methodology was used.

### 2.6. Antibacterial activity

AC synthesised using jasmine flower were evaluated for their ability to combat *E-Coli* and *Staphylococcus aureus* using the disc diffusion method. All samples were inoculated into sterile nutrient broth (Hi Media) (5 ml). Additionally, they were incubated for 3 to 5 h to bring the culture up to McFarland standards (106 CFC/ml). By spreading 100 ml of revived culture on Mueller Hinton-Agar/Hi Media using a spreader, 3 repetitions of each individual organism were organised. 50 ml samples of AC nanoparticles were put in one well (7 mm- diameter) (7 mm-diameter). All of the petri plates with organisms whose antibacterial effect was indicated by a zone of inhibition in mm were kept in the incubator at 37 °C for one day.

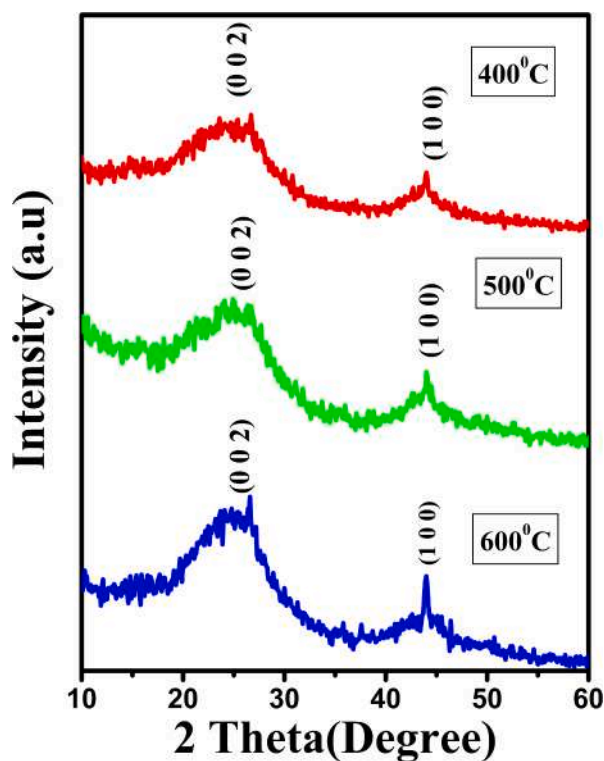


Fig. 1. XRD spectrum of Activated carbon (AC) NP's.

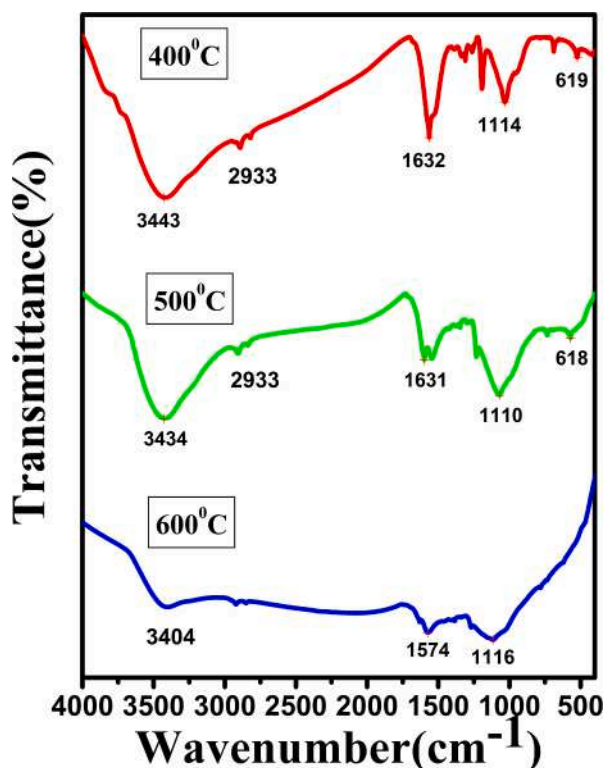


Fig. 2. FTIR spectrum of Activated carbon (AC) NP's.

### 3. Results and discussion

#### 3.1. X-Ray diffraction

Using XRD analysis, the phase and crystalline nature of activated

carbon were determined. Fig. 1 depicts the XRD pattern of activated carbon at various temperatures of annealing. The X-ray diffraction peaks at  $26^\circ$  and  $43.2^\circ$  correspond to Bragg reflection planes (002) and (100), respectively. The observed pattern corresponded to JCPDS. 7440-44-0 [19] is the file number. The peak at  $26^\circ$  shows disordered carbon or amorphous carbon, whereas the peak at  $44^\circ$  denotes the graphitic phase of carbon. Activated carbon's X-ray diffraction reveals a hexagonal graphite structure that corresponds well with JCPDS file number 75-1621 [20]. Due to an increase in the interplanar distance of the activated carbon, the noticeable peak visible at  $43.2^\circ$  progressively shifts upward when the annealing temperature is increased. The increase in annealing temperature facilitates the proper migration of atoms inside the lattice [21]. The small change in diffraction peak locations may be attributable to the presence of strain in the crystal structure, which is common in nanocrystalline produced using an eco-friendly process.

#### 3.2. Fourier Transform Infrared spectroscopy

FT-IR spectroscopy was utilized to analyse the functional groups of the studied activated carbon. Fig. 2 depicts the FT-IR spectra of activated carbon at various annealing temperatures. The designated band at 3744, 3434, 3443, 3393  $\text{cm}^{-1}$  corresponds to the O-H stretching vibration of alcohol, phenol, carboxylic acid, or water [22]. This frequency corresponds to the C-H stretching vibration of the aliphatic molecule. The band at 1631  $\text{cm}^{-1}$  corresponds to the C = C transition. Vibrational stretching of the aromatic ring [10]. The band seen at 1578  $\text{cm}^{-1}$  corresponds to the sulphate group's adsorption. The band found at 1337  $\text{cm}^{-1}$  corresponds to C-H asymmetries. C-O stretching vibrations are represented by the band at 1270  $\text{cm}^{-1}$ . The detected band at 1110–1114  $\text{cm}^{-1}$  corresponds to the vibrational bending of CO-H bonds. The peaks at 780 and 619  $\text{cm}^{-1}$  are from the O-H group [23,24]. Annealing temperature increases, water molecules are eliminated. Due to varying annealing temperatures, there is a little difference in peak shift and intensity.

#### 3.3. Scanning electron microscope with EDX

Using SEM and TEM photographs, the morphological analysis of activated carbon was observed. Fig. 3A-D displays SEM images of activated carbon heated to 400  $^\circ\text{C}$ , 500  $^\circ\text{C}$ , and 600  $^\circ\text{C}$ , respectively. The enhanced surface morphology of activated owing to a higher annealing temperature [25] is revealed by SEM pictures of irregular and agglomerated nanoparticles. A number of holes and cavities are present on the surface of activated carbon as a result of the emission of hot gases during the annealing procedure. Energy Dispersive X-ray Analysis was used to identify the components of the produced activated carbon nanoparticles (EDX). Carbon and oxygen peaks have been proven to exist. The remaining small peaks are attributable to plant extracts, and their quantities are negligible. Fig. 4 A-C depicts the elemental analysis spectrum.

#### 3.4. Transmission electron microscope

Transmission electron microscopy (TEM) images of activated carbon nanoparticles at 600  $^\circ\text{C}$  are shown in Fig. 5 A and B. The uneven forms of activated carbon result from the particles' synthesis. The photos demonstrate the activated carbon's high surface area, which can hinder the recombination process and potentially activate charge carriers. These approaches are quite effective at catalysis.

#### 3.5. Particle size analyser

Fig. 6 displays the DLS spectrum of activated carbon. At 400  $^\circ\text{C}$ , 500  $^\circ\text{C}$ , and 600  $^\circ\text{C}$ , the average particle size of activated carbon is 120 nm, 185 nm, and 190 nm, with polydisperse index values of 0.387, 0.375, and 0.345, respectively. According to the DLS spectrum, particle

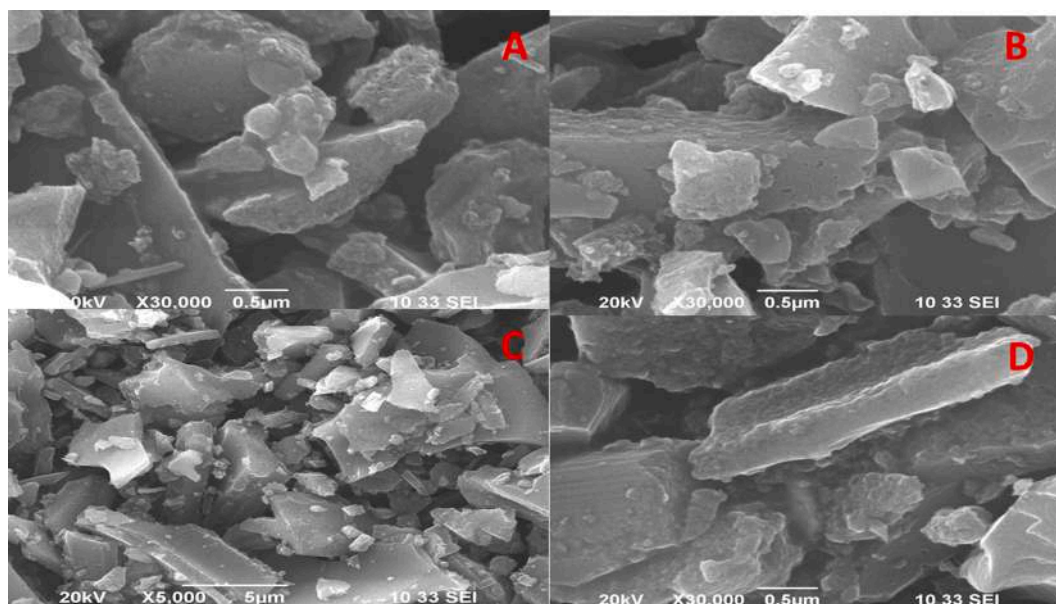


Fig. 3. SEM images of Activated carbon (AC) a. (400 °C), b (500 °C), c and d (600 °C) at different magnifications.

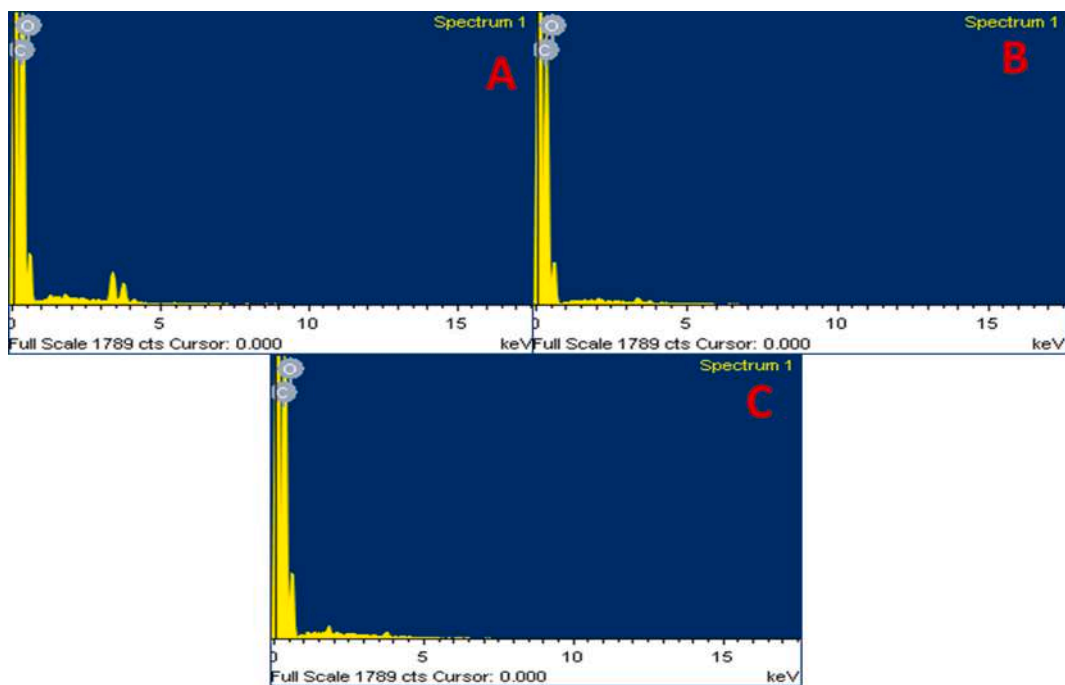


Fig. 4. (A-C) EDX spectra of Activated carbon (AC) NP's.

size values increase as the temperature rises.

### 3.6. UV-Visible spectroscopy

UV-Visible spectroscopy was used to study the optical characteristics of activated carbon. Fig. 7 depicts the absorbance spectra of activated carbon at various temperatures of annealing. The UV spectrum may be used to forecast surface morphology, oxygen deprivation, and contaminants. As a result of the electrical shift from the valance band to the conduction band, activated carbon with a preset absorbance peak at 249 nm absorbs light. The values of the energy band gap may be estimated using the Tauc plot.

$$\alpha h\nu = (h\nu - E_g)^n \quad (1)$$

Where  $\alpha$  is the absorption coefficient,  $\alpha$  represents a constant,  $h$  represents the energy of light, and  $E_g$  represents the energy bandgap [26]. The energy band gap values of activated carbon at temperatures of 400 °C, 500 °C, and 600 °C are 2.04 eV, 2.00 eV, and 1.94 eV, respectively. Due to an increase in annealing temperature, band gap values may fluctuate somewhat. Bandgap energy values decrease owing to an increase in crystallite size and annealing temperature. This phenomenon suggests that the interatomic distance increases when the amplitude of atomic vibrations grows in response to an increase in thermal energy. The annealing temperature decreased the optical band gap of activated carbon (Fig. 7 b-d), with 600 °C annealing reducing the optical band gap somewhat more than 400 °C and 500 °C annealing. However, the altering effects on the band gap of activated carbon did not appear to be

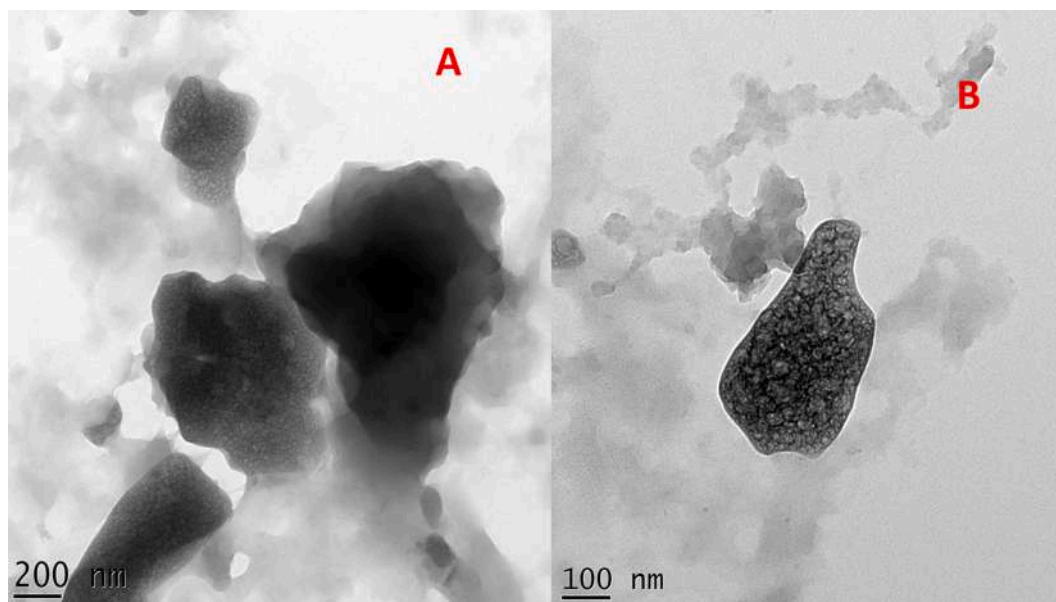


Fig. 5. A, & B TEM images of Activated carbon (AC) NP's at (600 °C).

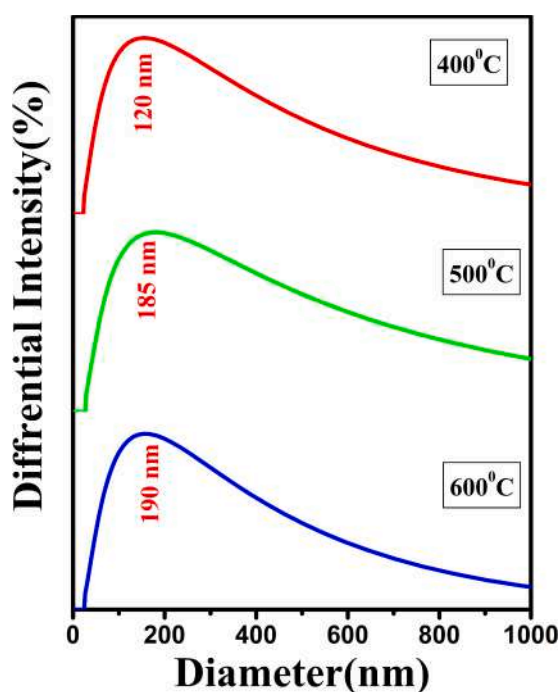


Fig. 6. (A-C) DLS spectra of Activated carbon (AC) NP's.

significant. The effects of thermal annealing on photocatalytic activity and its dependence on annealing temperature cannot be explained only by the optical bandgap decrease generated by thermal annealing, according to these results.

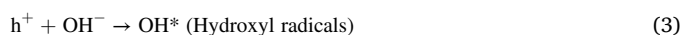
### 3.7. X-ray photoelectron spectroscopy

The XPS analysis was used to determine the surface electrical state and chemical composition. The XPS spectra of synthesised activated carbon (600 °C) were shown in Fig. 8. The synthesised Activated carbon contains C and O elements, according to the XPS survey spectra. Two unique peaks can be seen in the X-ray photoelectron spectroscopy (XPS) spectra of AC at energies of 284.5 and 532.2 eV, which are ascribed to

carbon and oxygen, respectively. Fig. 8 displays the XPS high resolution narrow scan C 1s spectrum. It has a large peak at 284.5 eV, which is consistent with a non-functionalized carbon, as well as contributions from aliphatic C sp<sup>3</sup> and C sp<sup>2</sup> hybridization, all of which are associated with the carbon surface. The existence of a C-C/C-H transition in an aromatic compound might be responsible for the binding energies 284.5 shown in the figure. The range 532.2 eV was where the surface O 1s peak was seen. The O 1s signal is not very responsive to the kind of oxygen ring bonds [27].

### 3.8. Photocatalytic activity

The photocatalytic activity of methylene blue (MB) was investigated by observing its photodegradation under visible light irradiation. Fig. 9 depicts the photocatalytic activity of activated carbons at various annealing temperatures. Activated carbon breaks down methylene blue quickly because its pores are very active and it has a lot of surface area. Maximum absorbance spectra of methylene blue are observed at 650 nm due to the absorption of the azo bond present in MB dye [28]. When ultraviolet light is allowed to penetrate through the surface of carbon, electrons from the valance band are stimulated into the conduction band, leaving holes. The positive holes interact with H<sub>2</sub>O to produce free radicals (OH<sup>•</sup>), whereas photo generated electrons interact with the surface of carbon to make superoxides (O<sub>2</sub><sup>-</sup>). Free radicals (OH<sup>•</sup>) and superoxides (O<sub>2</sub><sup>-</sup>) are a major cause of methylene blue degradation [29,30,31]. Together, these reactive radicals break down organic substances into CO<sub>2</sub>, H<sub>2</sub>O, and other minerals. Oxygen vacancies and defects turn into active centres to collect photo induced electrons during the photo catalytic reaction process. As a result, photo induced electron and hole recombination can be successfully suppressed. The absorption of O<sub>2</sub>, which is transformed into superoxide radicals (O<sub>2</sub><sup>•-</sup>) by contact with photo induced electrons, can also be aided by an increase in oxygen vacancies. These superoxide radicals are active in the oxidation of organic contaminants by generating additional radicals like OH<sup>•</sup> and H<sub>2</sub>O<sub>2</sub>. Fig. 10 is a diagram illustrating photocatalytic activity. Free radicals and superoxide react with dye molecules to produce carbon dioxide, water, and other organic chemicals. During deterioration, the following processes occur: Fig. 11.



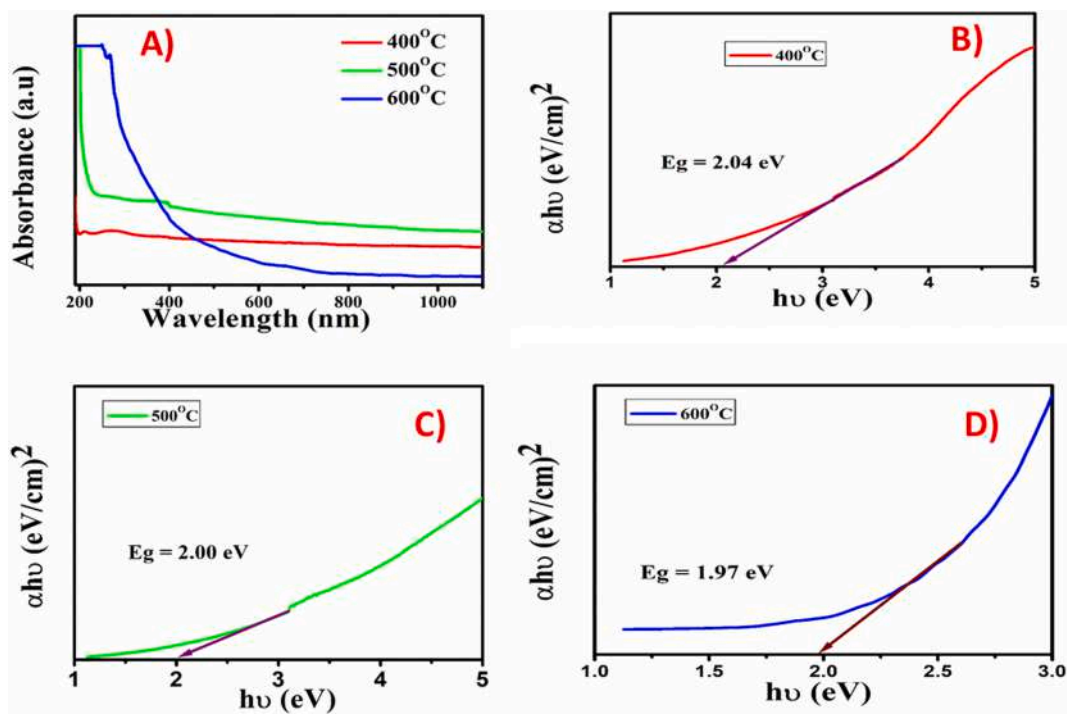


Fig. 7. A UV-absorbance spectrum and (B-D) Tauc plot of Activated carbon (AC) NP's.

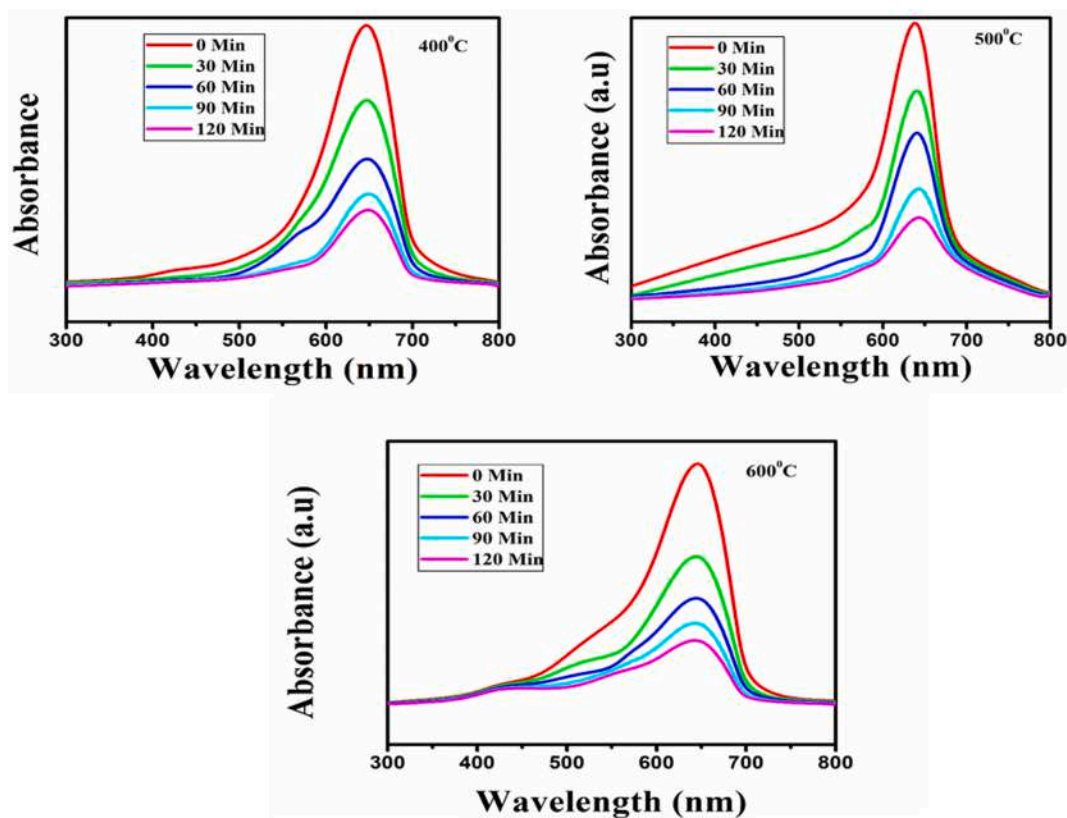
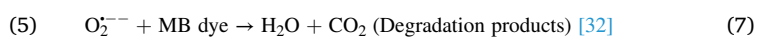
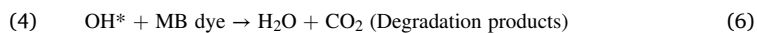
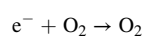
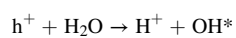


Fig. 8. (a-c) XPS spectra of activated carbon (600 °C).



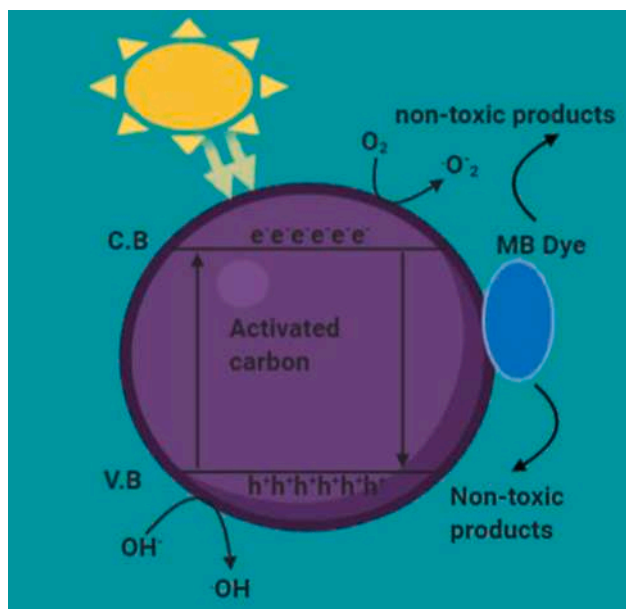


Fig. 9. Time-dependent UV-vis absorption spectra for degradation of MB (400 °C, 500 °C and 600 °C).

Activated carbon annealed at different temperatures (400 °C, 500 °C, and 600 °C) exhibits maximum degradation efficiencies of 86%, 90%, and 94% after 2 h, respectively. The conversion of the amorphous phase to the graphitic phase enhances the efficiency of degradation. Photocatalytic performance is improved by highly active pores and surface area [33]. The surface polarity, surface area, and aromaticity that result from the adsorption of organic pollutants [34] are crucial properties. During photodegradation, methylene blue is transformed to leuco methylene, resulting in a shift in hue from dark blue to colourless [35]. Several characteristics, including carrier recombination, particle size, surface area, surface acidity, and the presence of a greater number of hydroxyl groups, affect the photocatalytic activity of catalytic material.

In this study and previous research, 600 °C (sample 3) exhibits a greater percentage of degradation than 400 °C (sample 1). Due to the higher surface-to-volume ratio and low recombination rate of electron-hole pairs formed by optical exposure, the enhanced photocatalytic activity can be attributed to the many accessible surface states. As part of this investigation, the comparison in Table 1 shows how unique the study is about how methylene blue breaks down. Table 2.

### 3.8.1. Photocatalytic performance of activated carbon based photocatalyst

The results obtained are summarized in Table 1 and compared to earlier publications on photocatalyst, including activated carbon. Under the impact of UV or visible light, several nanostructures of photocatalyst based on activated carbon were utilised to degrade organic dyes. According to Table 1, activated carbon generated from egg shells can breakdown 82% of Methylene Blue dye for 120 min in the presence of sunshine, and the majority of reported activated carbon nanoparticles

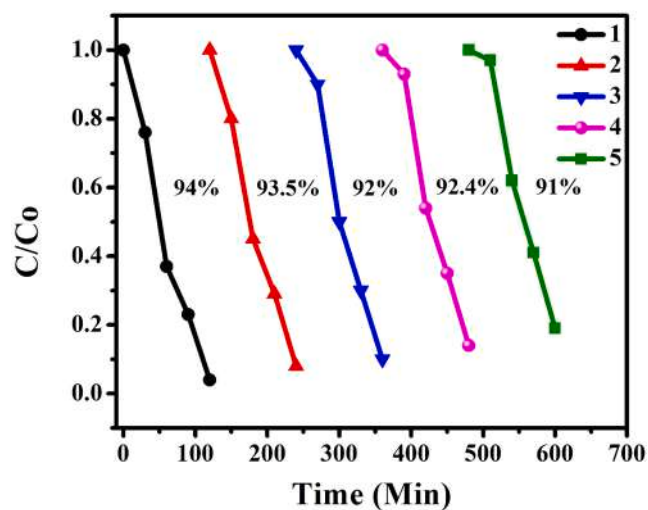


Fig. 11. shows reusability of activated carbon (600 °C) after 5 cycles.

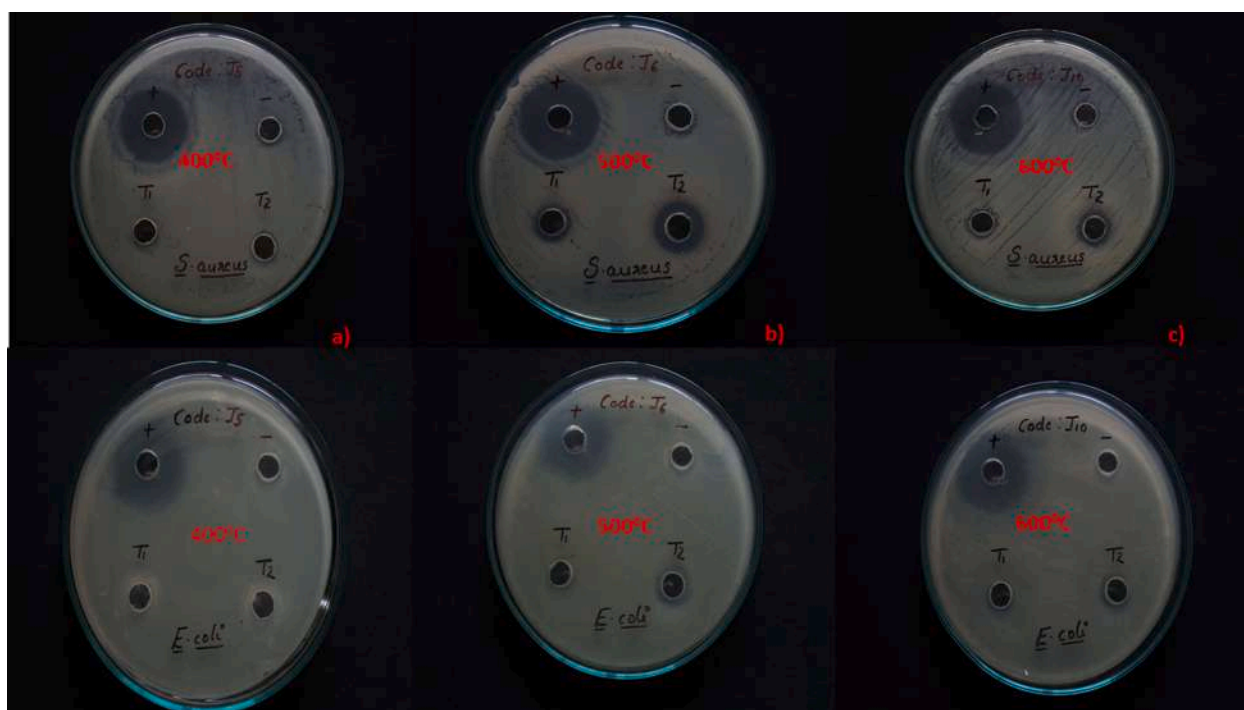


Fig. 10. Schematic representation of Photocatalytic degradation of MB dye.

**Table 1**

Photocatalytic performance of AC-based photocatalyst for the degradation of organic dyes in aqueous solution.

S.No	Nanocatalyst	Time	Dye	Degradation efficiency	References
1.	Activated Carbon (Coconut shell)	120 mins	Methylene blue	68%	[36]
2	Activated Carbon (coffee grounds)	150 Min	Methylene blue	20.97%	[37]
3	Activated Carbon (Jack fruit leaves)	30 Min	Methylene blue	84%	[38]
4	Activated Carbon (Egg shell)	180 Mins	Methylene blue	82.8%	[39]
5	Activated Carbon (fir bark)	180 Mins	Methylene blue	96%	[40]
6.	CuS, CdS and CuS-CdS	10 Mins	Methylene blue	80, 59 and 99.97%	[41]
7	La-doped ZnO	90 Mins	Methylene blue	88%	[42]
8	Zinc sulfide	60 Mins	Rhodamine B	93	[43]
9	ZnS	90 min	Brilliant green	88	[44]
10	ZnS, CdS and CuS	60 min	Bromothymol blue dye	63.88%, 83.42% and 46.23%	[45]
11	CdS and Sn-doped CdS	180 min	Methylene blue	91.39% and 97.56%	[46]
12	CdS, TiO <sub>2</sub> , CdS-TiO <sub>2</sub>	60 min	Acid Blue dye	68%, 09%, and 84%	[47]
13	ZnO-AC/A + P	60 min	Malacite Green and Congo Red	92%	[48]
14	ZnO-NR/ACF	120 mins	Methylene blue	90%	[49]
15	Nano Zinc Oxide/Nanohydroxyapatite	100 min	Methylene Blue	91%	[50]
16	Activated Carbon (Jasminum)	120 Mins	Methylene blue	94%	This Work

**Table 2**

Antibacterial efficacy of AC.

Nanomaterials	Bacterial pathogen	Zone of inhibitions (mm)	References
Zinc oxide	<i>Staphylococcus aureus</i>	29	[57]
	<i>Escherichia coli</i>	22	
Ag NPs	<i>Aspergillus niger</i>	25	[58]
	<i>Microsporium canis</i>	23	
	<i>Staphylococcus aureus</i>	17	
Ag-NPs	<i>Escherichia coli</i>	7	[59]
	<i>Staphylococcus aureus</i>	12	
Ag-NPs	<i>Escherichia coli</i>	15	[60]
	<i>Klebsiella pneumoniae</i>	10	
	<i>Salmonella Typhimurium</i>	20	
	<i>Salmonella Enteritidis</i>	20	
AC	<i>Aspergillus flavus</i>	21	[61]
	<i>Aspergillus Niger</i>	22	
	<i>Fusarium solani</i>	22	
	<i>Candida albican</i>	24	
	<i>S. cerevisiae</i>	23	
AC (600 °C)	<i>E scherichia coli</i>	12	Present work
	<i>Staphylococcus aureus</i>	10	

can degrade the dye for more than two hours. However, after 120 min of sun irradiation, 600 °C activated carbon had a maximum photodegradation efficiency of 94% for MB dye. In the near future, the activated carbon in its current state may be useful for the photodegradation of MB dye using sunlight.

### 3.9. Reusability

Fig. 12 shows reusability of activated carbon (600 °C) after 5 cycles. The long-term stability and reusability of the optimized AC photocatalyst (600 °C) towards the degradation of MB dye was studied under five cycles of sunlight exposure. The concentration of MB dye should be constant in each cycle, and the recovered centrifuged catalyst is used in subsequent cycles of the degradation process. The catalyst remains efficient and has remarkable photostability even after four cycles. Maximum MB dye degradation occurs after 120 min, and the efficiencies for the first, second, third, fourth, and fifth cycles are 94%, 93.5%, 92%, 92.4%, and 91%, respectively. The results of the present investigation therefore support the fact that AC formed during the photocatalytic destruction of MB dye under sunlight irradiation may exhibit excellent

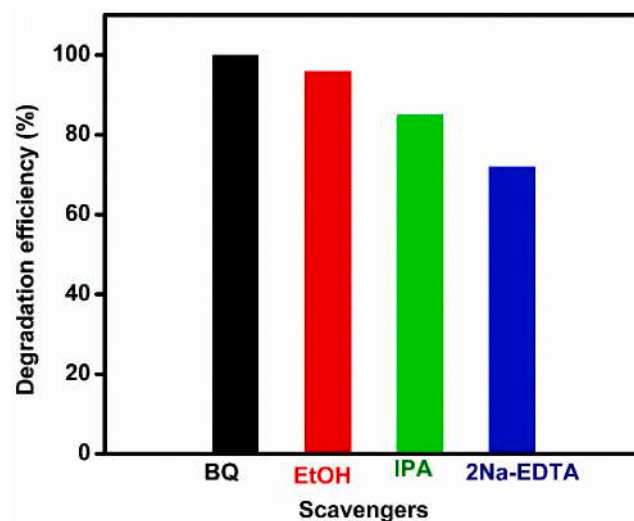


Fig. 12. Scavenger studies of activated carbon (600 °C).

photostability, stability and excellent photo corrosion resistance.

### 3.10. Scavenger studies

Fig. 12 shows the experiment for capturing reactive species while AC is being photocatalysis by sunlight. It was found that the addition of IPA and 2Na-EDTA scavengers reduced the photocatalytic efficacy of AC toward the degradation of MB dye. However, the degradation of MB in comparison to AC as a photocatalyst is not noticeably altered by the addition of ethanol and BQ. These findings suggest that the main reactive species involved in the photocatalytic breakdown of MB under solar illumination are holes and hydroxyl radicals.

### 3.11. Electrochemical impedance spectroscopy

Using an electrochemical analyzer in a typical three-electrode setup, measurements for Mott-Schottky (MS) and electrochemical impedance spectroscopy (EIS) were made. The working electrode's active area was 0.5 cm<sup>2</sup> by 1 cm<sup>2</sup>. EIS was carried out using an open circuit voltage of 0.2 V and an AC voltage amplitude of 5 mV, with a frequency range of



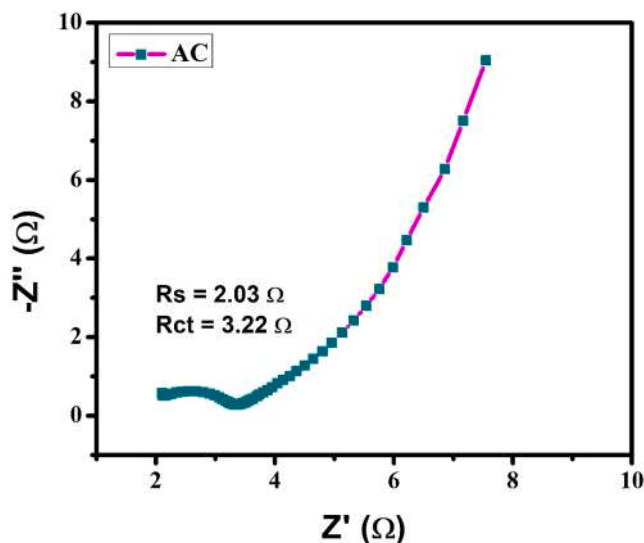


Fig. 13. Electrochemical impedance spectra of o activated carbon (600 °C).

0.1 Hz to 100 kHz. The analysis of the photogenerated charge separation and transfer during the photocatalytic process was done using the electrochemical impedance spectroscopy (EIS) of as prepared activated carbon. Generally, the Nyquist plot's semicircle's radius represents the rate of reaction taking place at the photocatalyst's surface. The reduced arc radius in the Nyquist plot (see Fig. 13) suggests that surface imperfections in the produced AC may be the cause of the rapid reaction rate and efficient charge transfer with decreased electrical resistance [51].

### 3.12. Morphological stability of prepared AC

TEM and SEM were used to assess the morphological stability of the recycled/recovered photocatalyst. According to TEM and SEM analysis, even after the third cycle of photodegradation, the AC authenticates that no structural change has been seen even after fifth cycle (Fig. 14). The fact that the degradation efficiency was still 96% even after three cycles further demonstrates the high photostability and reusability of the as-prepared AC under simulated visible-light irradiation.

### 3.13. Antibacterial activity

Fig. 15 depicts the antibacterial action of activated carbon. The antimicrobial effectiveness of activated carbon was evaluated using the disc diffusion technique. The antibacterial activity of gram-positive (*S. aureus*) and gram-negative (*E. coli*) bacteria was evaluated (*E. coli*).

Possible response mechanisms include the following:

1. Electrostatic interaction between nanoparticles and the cell wall membrane
2. Individual particle diffusion to the cell membrane.
3. Superoxides and free radicals are produced.

It is possible that superoxides and free radicals would arise since the experiment was conducted in a dark environment [52]. The interaction between the carbon surface and the negative cell wall membrane of *E. coli* results in electrostatic attraction, and the rupture of the cell wall leads to protein denaturation and cell death. The adsorption ability of carbon leads to effective antibacterial activity against *E. coli* [53]. The cell wall of Gram-negative bacteria has an outer lipopolysaccharide membrane and a thin layer of peptidoglycan, whereas the cell wall of Gram-positive bacteria has a thick layer of peptidoglycan [54]. These results suggest that not all positively charged NPs are more biocidal than negatively charged AC NPs toward the pathogens under study. Furthermore, it is challenging to say which pathogens are more vulnerable to exposure to positively charged AC NPs. In the literature, it is hypothesized that the electrostatic attraction between negatively charged microbial cell membranes and AC NPs with a positive surface charge can significantly increase the adhesion of AC NPs, giving positively charged AC NPs stronger antibacterial activities than negatively charged AC NPs. In this investigation, bio-formed activated carbon nanoparticle agglomerates were utilized. These large aggregates are more likely to penetrate the bacterial cell membrane and cause internal harm. It appears that direct interactions between activated carbon nanoparticles and the membrane surfaces of bacteria result in the mechanical rupture of the cell wall, which might be an efficient mechanism for the antibacterial activity of the sample. It was discovered that when the concentration of activated carbon-NPs increased, the size of the inhibitory zone grew. Crystalline structure and particle shape have a minimal effect on antibacterial activity, but surface area and concentration have a significant impact [55,56]. Gram-positive bacteria result in a smaller inhibition zone because it is difficult to destroy *S. aureus*' cell wall. Compared to amorphous carbon, the graphitic phase of carbon has superior antibacterial activity. Antibacterial activity is determined by the surface area, crystallinity, crystallite size, and particle size. A high concentration of activated carbon results in a larger inhibitory zone. The fact that the activated carbon material being studied is very good at killing bacteria shows that it is a great choice for treating wastewater.

## 4. Conclusion

This work used a hydrothermal carbonization method and a jasmine flower as biomass to make activated carbon. The hexagonal graphite phase of carbon is shown by the XRD pattern. FT-IR spectroscopy was used to identify the functional groups in activated carbon. The

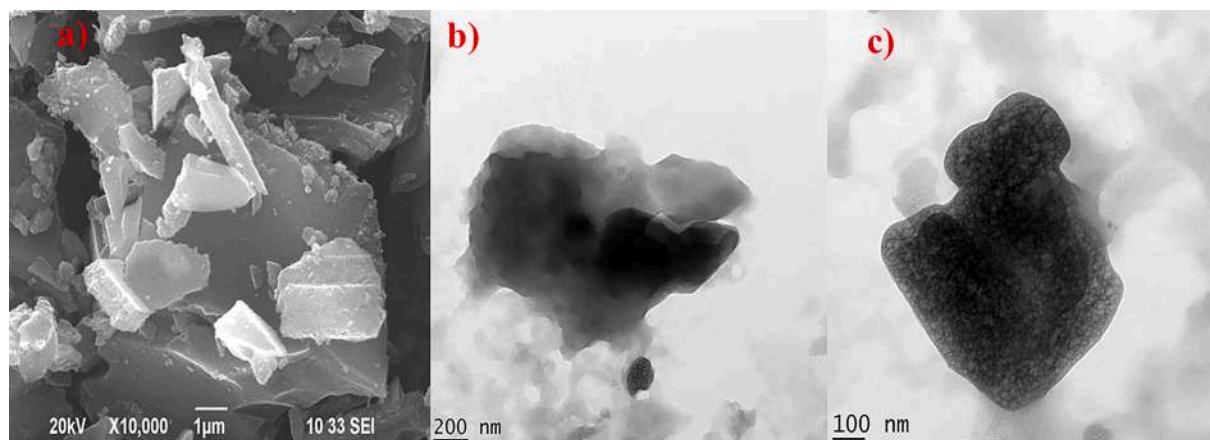


Fig. 14. a, b, c Morphological stability of activated carbon (600 °C) after 5 cycles.

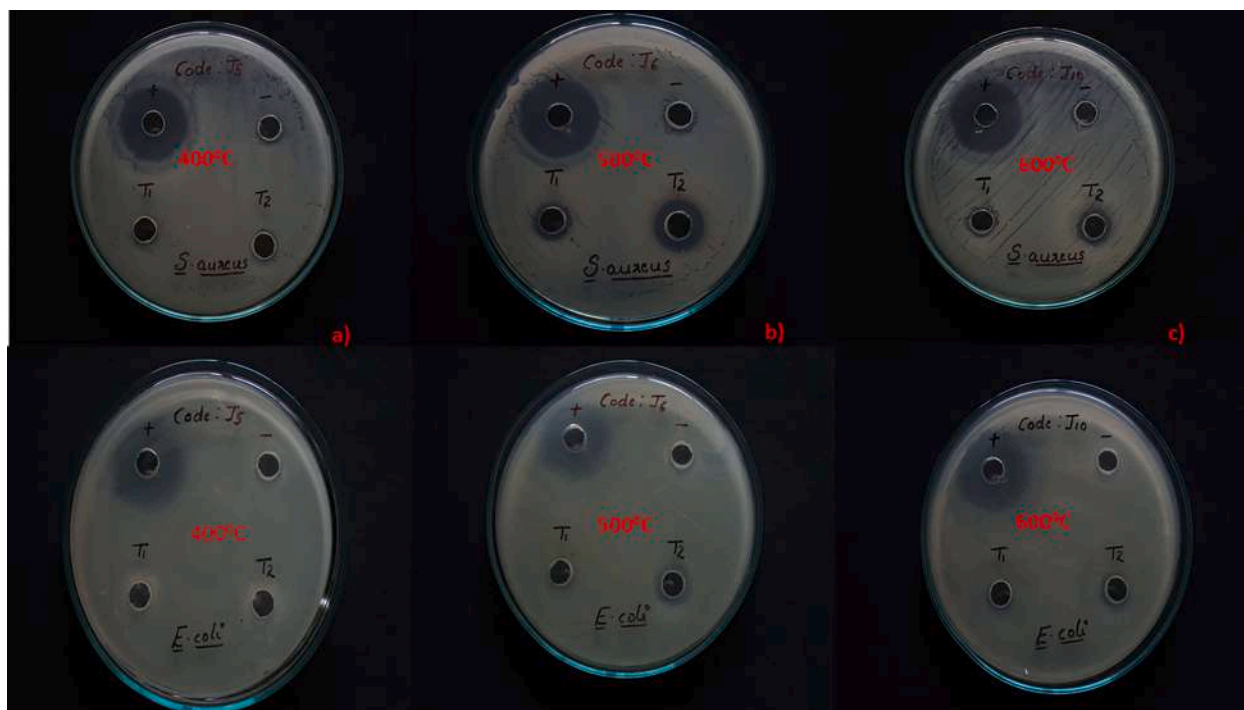


Fig. 15. Antibacterial activity of Activated carbon (400 °C, 500 °C and 600 °C).

production of agglomerated and irregular-shaped nanoparticles was shown by SEM and TEM. The optical absorption occurs at 249 nm in the UV spectrum. At different annealing temperatures, the energy band gap of activated carbon is 2.04 eV, 2.00 eV, and 1.97 eV (400 °C, 500 °C, and 600 °C), respectively. Under visible light irradiation, the greatest photocatalytic degradation of MB was recorded at 94 percent. As itself, activated carbon has strong antibacterial action. According to the findings, the generated activated carbon material is very suitable for wastewater treatment and environmental applications. The Nyquist plot's smaller arc radius verifies the efficient separation of photo-generated electron and hole pairs. The reusability investigations reveal that AC still display remarkable photostability and degradation efficiency even after four cycles. It is firmly believed that the prepared AC may serve as a potential photocatalyst for environmental remediation in the near future because they exhibit excellent photocatalytic performance even in their pristine form due to small crystallite size, high sunlight absorption, effective separation of charge carriers for a longer period of time, and high reduction and oxidation ability.

#### CRedit authorship contribution statement

**M. Amalanathan:** Supervision. **M. Aravind:** Synthesis, Manuscript Writing, Review, Conceptualization, Data curation. **M. Sony Michael Mary:** Formal analysis. **Nafis Ahmed:** Resources. **P. Velusamy:** Validation. **Kumari Subitha T:** Writing help. **Raazia Noreen:** Investigation. **Shafaqat Ali:** Investigation.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

Data will be made available on request.

#### Acknowledgement

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# Hydrothermally synthesized Ag-TiO<sub>2</sub> nanofibers (NFs) for photocatalytic dye degradation and antibacterial activity

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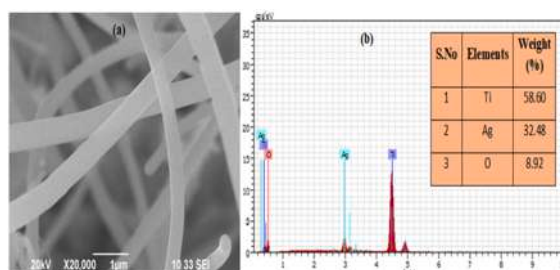
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## HIGHLIGHTS

- Ag nanoparticles modified with TiO<sub>2</sub> nanofibers was synthesized by the hydrothermal method.
- The Ag-TiO<sub>2</sub> Nanofiber achieved high photocatalytic performance toward the removal of Methylene blue.
- The Ag-TiO<sub>2</sub> Nanofibers displayed the attractive antibacterial efficacy against both gram positive and gram negative bacteria.
- The Ag-TiO<sub>2</sub> nanofibers are suitable for waste water treatment and biomedical applications.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

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Methylene blue  
Photodegradation  
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## ABSTRACT

This work successfully utilised eco-friendly green synthesis to produce Ag-TiO<sub>2</sub> nanofibers (NFs). As pollution and energy limitations have become global issues, there is an ongoing need to develop more effective catalysts through straightforward and environmentally friendly methods. The Ag-TiO<sub>2</sub> nanofibers (NFs) XRD pattern exhibits an anatase TiO<sub>2</sub> and FCC crystal structure of Ag nanoparticles. The SEM investigation revealed a nanofiber-like surface morphology. The Ag-TiO<sub>2</sub> nanofibers (NFs) exhibits an optical band gap energy is 2.5 eV. Methylene blue (MB), malachite green (MG), Congo red (CR), and crystal violet (CV) dye aqueous solutions were used to evaluate the photocatalytic performance of the synthesized Ag-modified TiO<sub>2</sub> nanofibers (NFs) under direct sunlight irradiation. The effects of catalyst size on the efficient breakdown of MB dye were also investigated. The optimum catalyst concentration was found to be at 0.02 mg/mL. At 120 min of direct sunlight, the highest photosynthetic degradation efficiency (DE percentage) of 94% was achieved for MB dye. Ag-TiO<sub>2</sub> nanofibers (NFs) have been demonstrated to have exceptional antibacterial activity against Gram-positive bacteria such as *Staphylococcus aureus* and Gram-negative bacteria *E-Coli*. Because of these great qualities, it seems

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likely that the Ag–TiO<sub>2</sub> nanofibers (NFs) made could be a great photocatalyst for getting dye pollutants out of wastewater.

## 1. Introduction

In recent years the most important challenges facing humanity now are the scarcity of clean water, growing population and pollution of existing water sources. There is a correlation between pesticides and other organic dyes in water sources and the transmission of water-borne diseases. A significant and widespread negative influence on the water supply is caused by impurities such as plastics, textiles, electronic trash, and industrial wastes. In recent years, addressing environmental issues resulting from huge releases of toxic substances has become a vital priority for the scientific community. Dye pollutants are exceedingly difficult to remove from wastewater. MB is a negative polar dye frequently employed in textile and artwork printing and painting. The negative effects of methylene blue are headaches, nausea, vertigo, and skin discolouration. Numerous technologies, including adsorption [Liu et al. \(2020\)](#), the biological process [Javaid et al. \(2011\)](#), membrane filtration [Kurt et al. \(2012\)](#), improved oxidation [Yasar et al. \(2013\)](#), and other physical and chemical processes, have been utilised to eliminate hazardous colours from wastewater. These procedures have the drawbacks of high temperatures, high pressure, energy consumption, and a longer time frame. Due to issues with effluent, sludge formation, and adsorbent repair, none of these approaches is superior for dye degradation. When dye molecules are exposed to sunlight they break down into carbon dioxide, water molecules, and simple mineral acids [Priyanka and Lens \(2022\)](#). Therefore, heterogeneous photocatalysis paves the way for an eco-friendly, cost-effective, and effective method of environmental clean-up ([Thakur et al., 2020](#); [Roongraung et al., 2020a,b](#)).

Gaurav K. [Upadhyay et al. \(2019\)](#) synthesized that ZnO: TiO<sub>2</sub> nanocomposite for removing methylene blue. The optical bandgap of the ZnO: TiO<sub>2</sub> nanocomposites has decreased from 3.30 eV to 3.10 eV. After 120 min, the ZnO-modified TiO<sub>2</sub> nanocomposite degrades at its fastest rate, between 75 and 90%. [Moradi et al. \(2018\)](#) reported that under UV irradiation, the magnetic NiFeO<sub>4</sub>@ZnO nanocomposite degrades direct blue dyes and reactive blue dyes. NiFeO<sub>4</sub>@ZnO nanocomposites degrades natural blue dyes and reactive blue dyes by 98.5% and 96.5%, respectively. [Mukhopadhyay et al. \(2016\)](#) synthesized that plasmonic Au-coated ZnO/TiO<sub>2</sub> catalysts completely degrades under CR and MB under UV light irradiation. According to [Aqeel et al. \(2020\)](#) sol-gel process was used to prepare the nano photocatalyst Zr/Ag/TiO<sub>2</sub>. Zr/Ag/TiO<sub>2</sub> nanocomposites have 93% dye degradation efficiency. [Santos et al. \(2015\)](#) used a hydrothermal technique to prepare Ag/TiO<sub>2</sub> nanocomposite to decolourize tartrate azo dye. According to [Kumar et al. \(2020\)](#) the photocatalytic activity of the Ag/TiO<sub>2</sub> composites degrades 78 percent of methyl orange dye after 180 min.

Noble metal nanoparticles have strong Surface Plasmon Resonance (SPR) properties and a high electron trapping capacity. In the present research work aims to synthesis and analyse Ag–TiO<sub>2</sub> nanofibers (NFs) for the effective photodegradation of Methylene blue (MB), malachite green (MG), Congo red (CR), and crystal violet (CV) dye aqueous dye solution under solar irradiation. Ag–TiO<sub>2</sub> nanofibers (NFs) may be able to absorb UV and visible light from the sun and attract additional dye molecules to the surface, which is a good way to break down organic dyes. The most important factors for enhancing photocatalytic activity are metal ions dopants (Cu, Co, Ag, Au), composite networks, and the different kinds of light sources used (UV/Visible or sunlight). Metal doping can reduce charge carrier recombination and improve photocatalyst visible light absorption based on ZnO and TiO<sub>2</sub>.

## 2. Materials and methods

### 2.1. Materials

The ingredients Titanium Tetra Isopropoxide (TTIP), Silver nitrate (AgNO<sub>3</sub>), and Methylene blue (C<sub>16</sub>H<sub>18</sub>ClN<sub>3</sub>S) were purchased from Sigma Aldrich. Without any additional purification, all chemicals and reagents are used.

### 2.2. Synthesis of Ag–TiO<sub>2</sub> nanofibers (NFs)

Ag–TiO<sub>2</sub> nanofibers (NFs) were synthesized by employing a simple and environmentally friendly hydrothermal method [Aravind et al. \(2021\)](#). After adding 10 mL of titanium tetra-isopropoxide (TTIP) to a beaker with a capacity of 100 mL, the next step was to add 5 mL of jasmine flower extract and 20 mL of distilled water. The solution was constantly stirred at a pace of 400 revolutions per minute (rpm). The titanium solution should now have added 0.1 M of an AgNO<sub>3</sub> solution. The solution was kept warm in an autoclave made of stainless steel and heated for one day in a muffle furnace at a temperature of 180 °C. Calcination took place for 6 h at a temperature of 500 °C [Wang et al. \(2020\)](#).

### 2.3. Characterizations of Ag–TiO<sub>2</sub> nanofibers (NFs)

The Panalytical X-Pert Pro diffractometer was used to measure powder X-ray diffraction. The Shimadzu Prestige 20 IR-Spectrophotometer was used to record the FT-IR spectrum with an area of 400–4000 cm<sup>-1</sup>. Scanning Electron Microscopes with Energy Dispersive X-Ray Spectroscopy (Jeol JSM 6390 and QuinTox KM9106) were used to analyse surface micro-morphology and their elemental analysis. A Jasco V630 UV-Visible Spectrophotometer was used to measure UV-visible absorbance spectra. Dielectric measurements were made with a CHI604E electrochemical analyser and a Hioki LCR impedance analyser.

### 2.4. Photocatalytic measurement

The degradation of MB aqueous dye in visible light was investigated. The Ag–TiO<sub>2</sub> nanofibers (NFs) were distributed in a 100 mL aqueous MB dye. So that adsorption and desorption may occur properly before irradiation can take place. The solution was ultrasonically agitated for 60 min inside a dark room. Every 30 min, 5 mL of solution was collected and centrifuged at 3000 rpm for 10 min. The temperature of the reaction mixture was kept constant at 37 °C. The photodegradation behavior was evaluated using a UV-Vis analyser. Similarly, different quantities of catalysis (0.005 mg–0.02 mg) of Ag–TiO<sub>2</sub> were used to assess the catalytic effectiveness of the samples. The following equation is used to determine the degradation efficiency (DE) of dye.

$$\text{Degradation Efficiency (\%)} = (C_0 - C) / C_0 \times 100 \% \quad (1)$$

where C<sub>0</sub> – Initial concentration of dye solution.

C – Final concentration of dye solution [Ahmad et al. \(2020\)](#).

### 2.5. Antibacterial properties

The antibacterial properties of Ag–TiO<sub>2</sub> nanofibers (NFs) were investigated using disc diffusion. The antibacterial activity of Ag–TiO<sub>2</sub> nanofibers (NFs) was examined using gram-positive (*S. aureus*) and gram-negative (*E. coli*) bacterial pathogens [Wong et al. \(2020\)](#). 8 (milli

meters) mm wells were punched in Mueller Hinton Agar (MHA) and wiped with positive and negative strains. In each well was poured a solution of prepared Ag-TiO<sub>2</sub> nanofibers (NFs) of varying concentrations. The agar plate was incubated for 24 h at 37 °C. The inhibitory layer was measured in millimetres Rao et al. (2019).

### 3. Results and discussion

#### 3.1. XRD analysis

Fig. 1 a) Demonstrates the XRD pattern of Ag-TiO<sub>2</sub> nanofibers (NFs). The Bragg reflection planes (101), (110), (004), (111), (102), (200), (105), (211), (204), (220), and (116) correspond to the diffraction peaks 2(θ) at 25.56°, 27.48°, 36.17°, 38.28°, 41.36°, 48.37°, 54.54°, 56.92°, 62.81°, 64.35°, and 69.20°. The diffraction peaks measured at 38.28°, 48.37°, and 64.35° correlates to the FCC crystal structure of Ag-TiO<sub>2</sub> nanoparticles. The detected XRD peaks precisely matched with the JCPDS card numbers 07-6173 and 04-0774 Roongraung et al. (2020). The average crystallite size of Ag-TiO<sub>2</sub> nanofibers (NFs) is 33 nm (nm). In the XRD pattern of Ag-TiO<sub>2</sub> nanofibers, dual phases consisting of a tetragonal anatase phase and a face-centred cubic lattice of silver nanoparticles are seen. The Ag nanoparticles couldn't get into the TiO<sub>2</sub> crystal lattice, so they gathered on its surface.

#### 3.2. UV-visible absorbance spectroscopy

Fig. 1 (c and d) depicts the UV-visible and Tauc plots of Ag modified

TiO<sub>2</sub> nanofibers (NFs). The Ag modified TiO<sub>2</sub> nanofibers reveals the absorbance peak reaching between 208 and 396 nm (NFs) Liang et al. (2022). The redshift is triggered by the presence of Ag-nanoparticles on the surface of the TiO<sub>2</sub> nanostructure. Because of the localized SPR effect, the plasmonic Ag nanoparticles in the TiO<sub>2</sub> catalyst may easily absorb light and excite the surface electron for transmission to an acceptor Li et al. (2018). The Tauc plot was used to obtain the optical band gap values,

$$h\nu = A (h\nu - E_g)^n / \alpha \quad (2)$$

where  $\alpha$  is the optical absorption coefficient,  $E_g$  is the bandgap energy,  $A$  is an optical constant, and  $n$  indicates the transition order Arifin et al. (2022). The optical band gap values of the Ag-TiO<sub>2</sub> nanofibers (NFs) determined are 2.5 eV. While Ag nanoparticles have been added on the surface of TiO<sub>2</sub> nanoparticles, compared to commercial TiO<sub>2</sub> nanoparticles, the bandgap gradually decreases. When Ag nanoparticles are present on the surface of the TiO<sub>2</sub> nanostructure, a huge quantity of photons with a longer wavelength are absorbed. It makes photocatalysis work better. Electrons are excited from the VB (valance band) to the CB (conduction band) and subsequently shifted to the Ag fermi level. UV spectra result in a decreased photoelectron carrier recombination rate Shen et al. (2022).

#### 3.3. Fourier transform -infra red (FT-IR) spectroscopy

Fig. 1 b) shows the vibrational spectra of as-prepared Ag-TiO<sub>2</sub> nanofibers (NFs) using jasmine flower extract. The band obtained at

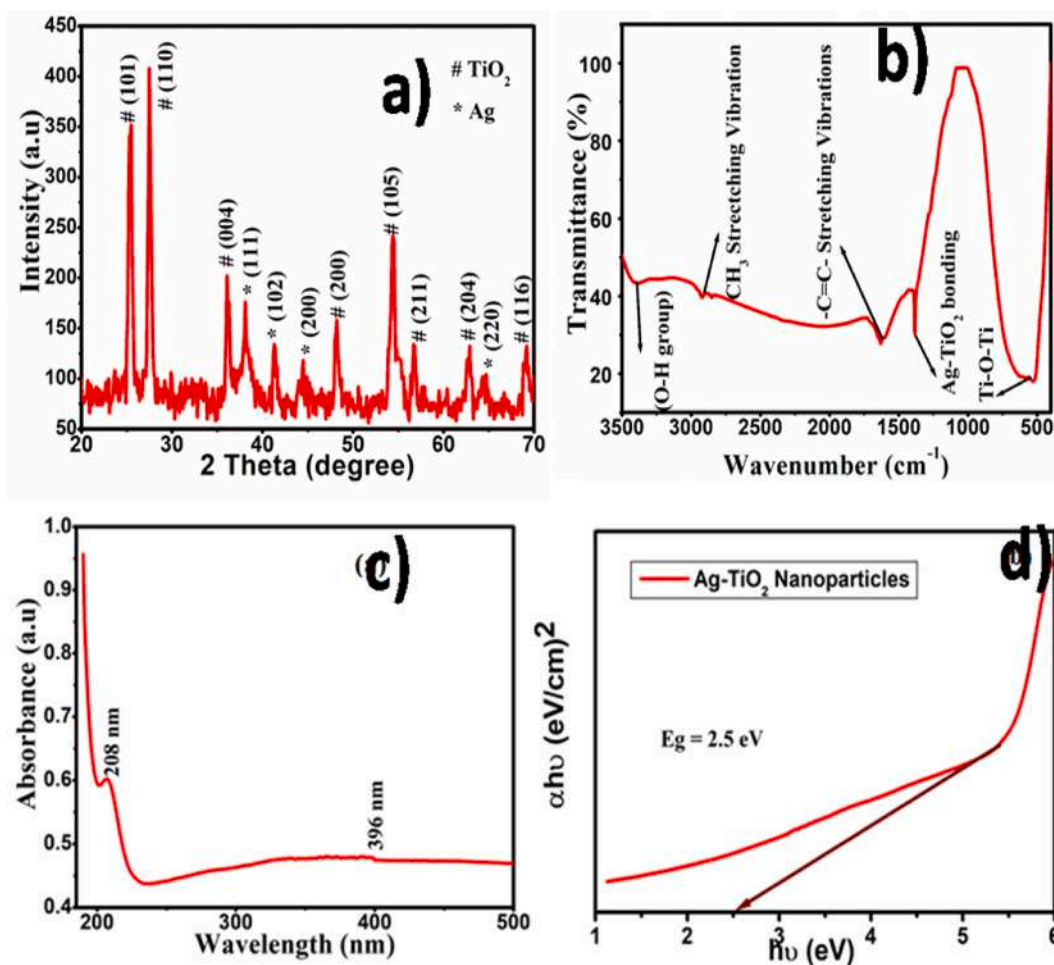


Fig. 1. a) XRD pattern of Ag-TiO<sub>2</sub> nanofibers (NFs), b) FT-IR spectra of Ag-TiO<sub>2</sub> nanofibers (NFs) using jasmine flower extract (c and d) UV-visible absorbance spectra and Tauc Plot of Ag-TiO<sub>2</sub> nanofibers (NFs).

3385.3  $\text{cm}^{-1}$  denotes the hydroxyl (O–H) groups Zhang et al. (2012). The peak at 2851  $\text{cm}^{-1}$  corresponds to the  $-\text{CH}_3$  stretching mode of vibration Ashraf et al. (2020). The  $-\text{C}=\text{C}$ -aromatic stretching vibrations band obtained at 1631.30  $\text{cm}^{-1}$  Jaber et al. (2020). The band observed at 1355  $\text{cm}^{-1}$  represents the Ag–TiO bond. The signal at 1355  $\text{cm}^{-1}$  supports silver NPs deposition on the surface of TiO<sub>2</sub> NFs. The Ti–O–Ti vibrations in Ti are seen by the 528  $\text{cm}^{-1}$  peak Carvalho et al. (2018).

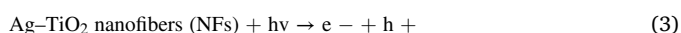
### 3.4. Scanning electron microscope with elemental dispersive analysis X-ray spectrum

Fig. 2 (a and b) display the SEM and EDAX images of the Ag–TiO<sub>2</sub> nanofibers (NFs) respectively. The surface morphology demonstrates that a vast number of nanofibers made of TiO<sub>2</sub> are regularly aligned Kang et al. (2019). When Ag nanoparticles are decorated on the surface of the nano-structured TiO<sub>2</sub> nanofibers results in the size and form of the composites may be controlled to a certain extent. The EDAX spectrum of Ag–TiO<sub>2</sub> nanofibers (NFs) reveals the presence of key components, including silver, titanium, and oxygen.

### 3.5. Photocatalytic performance

#### 3.5.1. Mechanism of photodegradation of dye molecules

The photocatalytic dye degradation of Methylene Blue is shown in Fig. 3. When sunlight falls on the surface of Ag–TiO<sub>2</sub> NFs, photoelectrons ( $e^-$ ) may be excited from the valance band to the conduction band by leaving holes ( $h^+$ ) in the Valance band. Photo generated  $e^-$  and  $h^+$  migrated to the Ag–TiO<sub>2</sub> nanofibers (NFs) surface, preventing electron hole pair recombination. However, because Ag has a higher fermi energy level than TiO<sub>2</sub>, electrons move from Ag to TiO<sub>2</sub>. When light (visible) is irradiated on the surface of Ag–TiO<sub>2</sub> nanofibers (NFs), the Schottky barrier effect mechanism causes Ag and TiO<sub>2</sub> to form new  $F_e$  (Fermi energy) levels and change some values, resulting in improved photocatalytic activity. Water molecules infiltrate the gaps in the valance band, allowing hydroxyl radicals ( $\bullet\text{OH}$ ) and hydrogen ions ( $\text{H}^+$ ) to get through. Superoxides ( $\text{O}_2^-$ ) are formed when photo generated electrons absorb dissolved oxygen. Reactive hydroxyl groups and superoxide react with aqueous solutions to produce  $\text{CO}_2$  and  $\text{H}_2\text{O}$  as by-products Kang et al. (2019).



The accumulation of noble metal (Ag) nanoparticles to the surface of a TiO<sub>2</sub> catalyst prevents the trapping of electron hole pairs and decreases the rate of electron-hole pair recombination. Due to the SPR effect, the incorporation of silver nanoparticles increases the visible light absorption capability of TiO<sub>2</sub> nanoparticles and their catalytic activity Chen et al. (2012). TiO<sub>2</sub> is one of the most effective photocatalysts for removing persistent contaminants such as organic dyes, medicinal chemicals, bacteria, and viruses. The rapid recombination of charge carriers and the inefficient utilisation of light remain significant hurdles to its broad application. By altering the TiO<sub>2</sub> lattice with the noble metal silver, it is possible to enhance the catalytic performance of TiO<sub>2</sub> and shift its photocatalytic response to the UV to the visible light spectrum.

#### 3.5.2. Effect of catalyst

The impact of the initial photocatalyst concentration was investigated by increasing the initial Ag–TiO<sub>2</sub> nanofibers (NFs) concentration from 0.005 mg to 0.02 mg per 100 ml in MB dye solution, which can be seen in Fig. 3 (a). When the amount of photoactive catalyst was increased from 0.005 to 0.02 mg, the photocatalytic activity increased, perhaps due to an increase in the active sites on the catalyst surface. Over 0.02 mg of catalyst decreased photocatalytic activity due to the optical scattering and light screening effects of nanoparticles. It is due to particle aggregation, a barrier to light irradiation. The degradation efficiency is diminished with a catalyst concentration of 0.005 mg/mL. Doping metal with TiO<sub>2</sub> may function as cationic dopants, enhance its sensitivity to visible light, and prevent recombination by modifying its electronic band structure. At the end of 120 min, the Ag–TiO<sub>2</sub> nanofibers (NFs) (0.02 mg) may disintegrate at a maximum rate of 94% Palaniswamy et al. (2021).

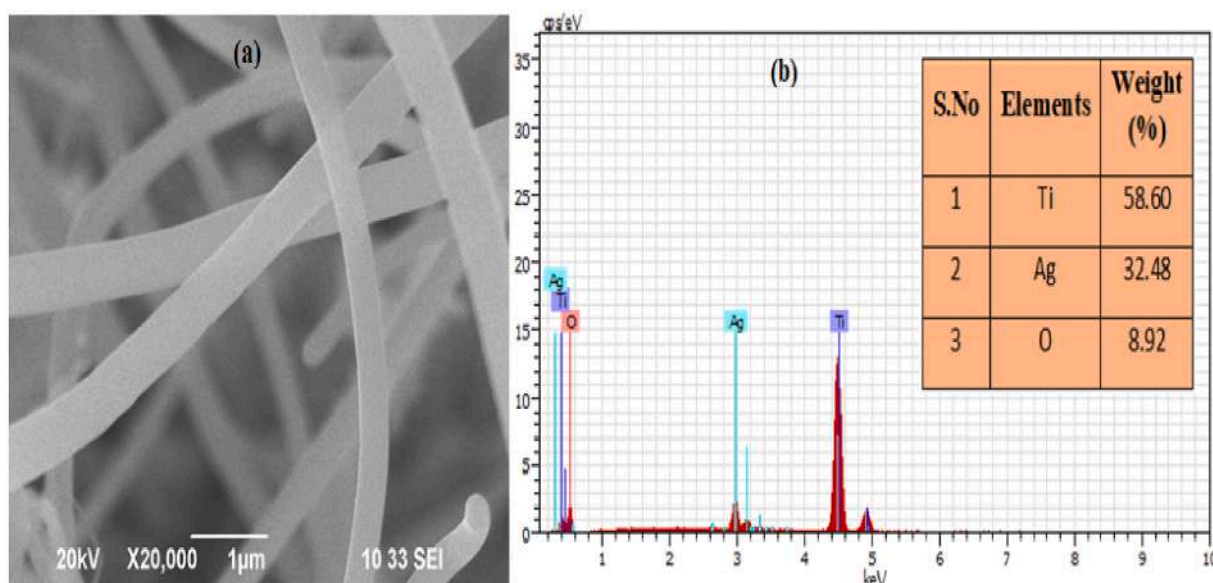


Fig. 2. (a, b) SEM and EDAX spectra of Ag–TiO<sub>2</sub> nanofibers (NFs).

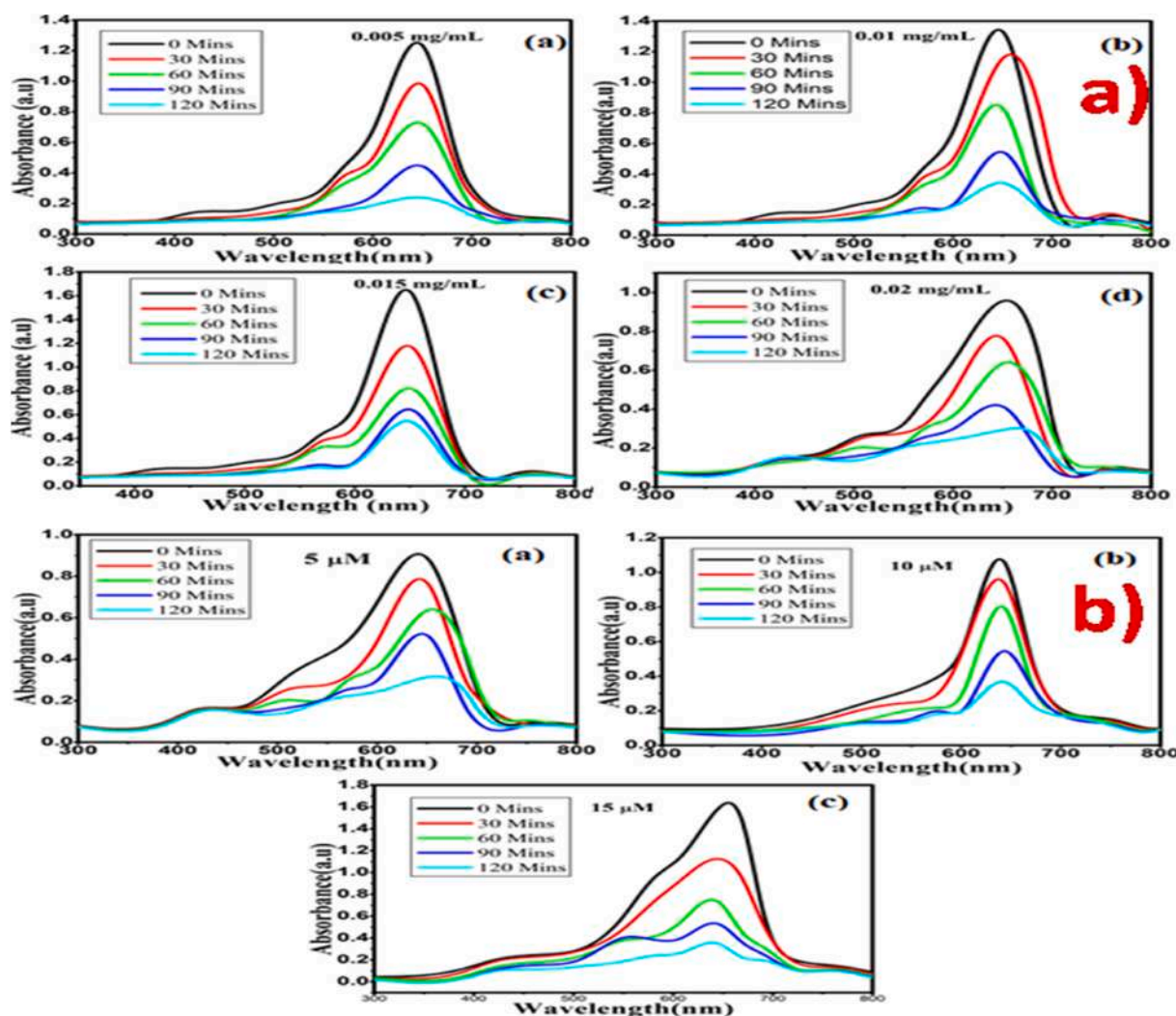


Fig. 3. (a and b): Time-dependent absorbance spectra (UV-Vis) of MB dye degradation (Effect of catalyst 0.005 mg to 0.02 mg and effect of dye dosage 5  $\mu\text{M}$  to 15  $\mu\text{M}$ ).

### 3.5.3. Effect of the dye concentration

Fig. 3 b) illustrates the influence of diminishing efficiency on MB concentrations (5, 10, and 15  $\mu\text{M}$ ). As the dye concentration increases, the effectiveness of photocatalytic degradation decreases. At lower concentrations, more active sites from MB molecules are adsorbed by Ag-TiO<sub>2</sub> NFs. Increasing the dye concentration prevents photons from ever reaching the Ag-TiO<sub>2</sub> nanofibers (NFs) surface, reducing the dye removal efficiency. Increased dye concentrations reduce the travel length of photons, hence decreasing the light-activated catalyst [Palanisamy et al. \(2020\)](#).

### 3.5.4. Photocatalytic degradation of malachite green

Malachite green, commercial dye effluents, was used as a target Organic Compound Model (OCM) to assess the photo activity of the fluorescent Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst. In light adsorption, the Ag-TiO<sub>2</sub> nanofibers (NFs) performance was inadequate; only a small percentage (3–4%) of the dye was degraded after 60 min. In Fig. 4 a), the Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst reveals the maximum photocatalytic degradation efficiency of 92% at the end of 1 hrs, when exposed to visible light. As stated in the optical characteristics, the Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst has low band-gap energy. Radical recombination outpaces separation when exposed to UV light, whereas electron-hole production is expected, and recombination is weak when exposed to visible light. Malachite green photodegrades in the sunshine

without energy, which benefits both financially and environmentally. The negatively charged catalysts can easily be coated with cationic MG dye, and the Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst demonstrates outstanding photocatalytic performance.

### 3.5.5. Photocatalytic degradation of crystal violet

The crystal violet photodegradation estimates the catalytic performance of Ag/TiO<sub>2</sub> NFs under sunlight irradiation for 60 min. Fig. 4 b) Shows the time-dependent UV-Vis absorbance spectra of crystal violet dye degradation. The first experiment subjected the CV solution to sunlight irradiation without using photocatalyst. According to the findings, solar radiation causes materials to degrade at roughly 3%. Degradation was barely detectable.

On the one hand, we observe that the photocatalytic activities of Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalysts in sunlight are distinct. After 60 min of direct sunlight exposure, the photodegradation efficiency for Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst shows 80.3%. The photocatalytic activity was often sensitive to the crystalline, surface OH groups, particular surface area, and photocatalyst surface roughness. As a result, the Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst exhibits superior photocatalytic performance when exposed to visible radiation. Doping ions will increase the number of electrons and hole traps in the Ag-TiO<sub>2</sub> nanofibers (NFs) photocatalyst lattice, fastening the charge carriers and preventing the recombination rate of photo generated e<sup>-</sup> and h<sup>+</sup>,



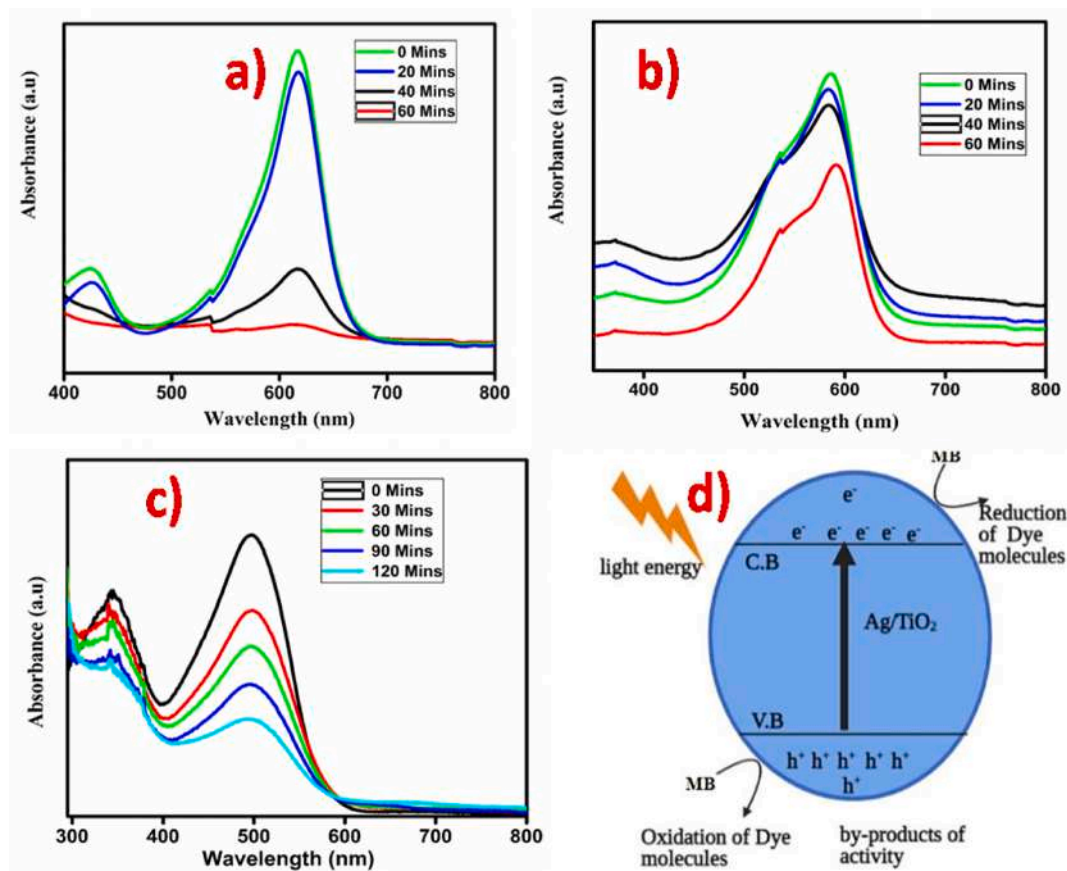


Fig. 4. (a–c) Time-dependent UV–Visible absorbance spectra of Malachite green, Crystal violet and Congo red and d) Possible reaction mechanism of dye degradation.

improving catalytic activity.

### 3.5.6. Photocatalytic degradation of Congo red (CR) dye

The decolouration of dye with initial concentrations (10 mg/L) CR under solar irradiation was used to evaluate the photocatalytic degradation efficiency of Ag–TiO<sub>2</sub> NFs. Fig. 4 c) shows the time-dependent UV–Vis absorbance spectra of CR dye degradation. The maximum absorbance ( $\lambda_{\max}$ ) of the supernatant dye solution determines the concentrations of the CR dye at 498 nm. The photocatalytic performance was improved, possibly due to the enhanced surface to volume ratio and band structure alteration of the Ag NPs. It effectively limited the recombination of photogenerated ( $e^-/h^+$ ) pairs. CR dye degradation using Ag–TiO<sub>2</sub> nanofibers that were hydrothermally produced (NFs). At 492 nm, CR exhibits the highest absorption. The decline in CR dye's maximal absorption at regular intervals of 30 min is indicative of dye degradation. The activity of the catalysts was initially examined using 0.02 mg of the catalyst exposed to visible light for 120 min. However, in 120 min, Ag–TiO<sub>2</sub> nanofibers (NFs) demonstrated 80.5% photocatalytic degradation. The increased photocatalytic activity of Ag–TiO<sub>2</sub> nanofibers (NFs) implies that the addition of silver greatly enhances Ag–TiO<sub>2</sub> nanofibers (NFs) catalytic activity.

However, only about 80.5% of CR was decoloured for 50 mg/L concentrations. Therefore, when the original CR content increased, the photodegradation efficiency of CR photocatalysis by the Ag–TiO<sub>2</sub> nanofibers (NFs) powder also dropped. Two factors are primarily responsible for the decline in the semiconductor's degrading efficiency as CR concentration increases. More molecules are adsorbed on photocatalyst when the CR concentration increases, lowering their active sites. Therefore, as more of the catalyst surface is occupied, the production of hydroxyl radicals will be reduced.

On the other hand, raising the CR can decrease the number of

photons that reach the catalyst surface. By adsorbing the light, CR molecules reduce photons' ability to excite photocatalyst particles. Consequently, photo degradation's effectiveness dropped. Under visible-light irradiation, the Ag–TiO<sub>2</sub> nanofibers (NFs) demonstrate effective photocatalytic activity in the breakdown of CR.

### 3.6. Ag–TiO<sub>2</sub> based photocatalyst

The catalytic performance of an Ag–TiO<sub>2</sub>-based photocatalyst was compared with some other organics and is tabulated and summarized in Table 1. Table 1 shows that previously published Ag–TiO<sub>2</sub> catalysts could decolourize 79.8% of Methylene Blue dye in 150 min, while most Ag–TiO<sub>2</sub> composites could take more than 2 h to do the same. Compared to ternary composite materials, Ag–TiO<sub>2</sub> nanofibers (NFs) produced hydrothermally has a high photodegradation efficiency of 94% when exposed to sunlight (see Table 2).

### 3.7. Structural and morphological stability of Ag–TiO<sub>2</sub> nanofibers (NFs)

Powder XRD and SEM were used in the study to investigate the structural and morphological stability of Ag–TiO<sub>2</sub> nanofibers (NFs) (Fig. 5 a, b). According to the XRD pattern, the initial crystalline phase and structure of the Ag–TiO<sub>2</sub> nanofibers (NFs) subjected to photodegradation did not change. Because dye molecules were incorporated into the material, the SEM pictures show a few agglomerations, leading to subtle morphological changes when the material was degraded.

### 3.8. Reusability

The stability and reusability of the optimized Ag–TiO<sub>2</sub> nanofibers (NFs) towards the dye degradation of MB were studied under sunlight

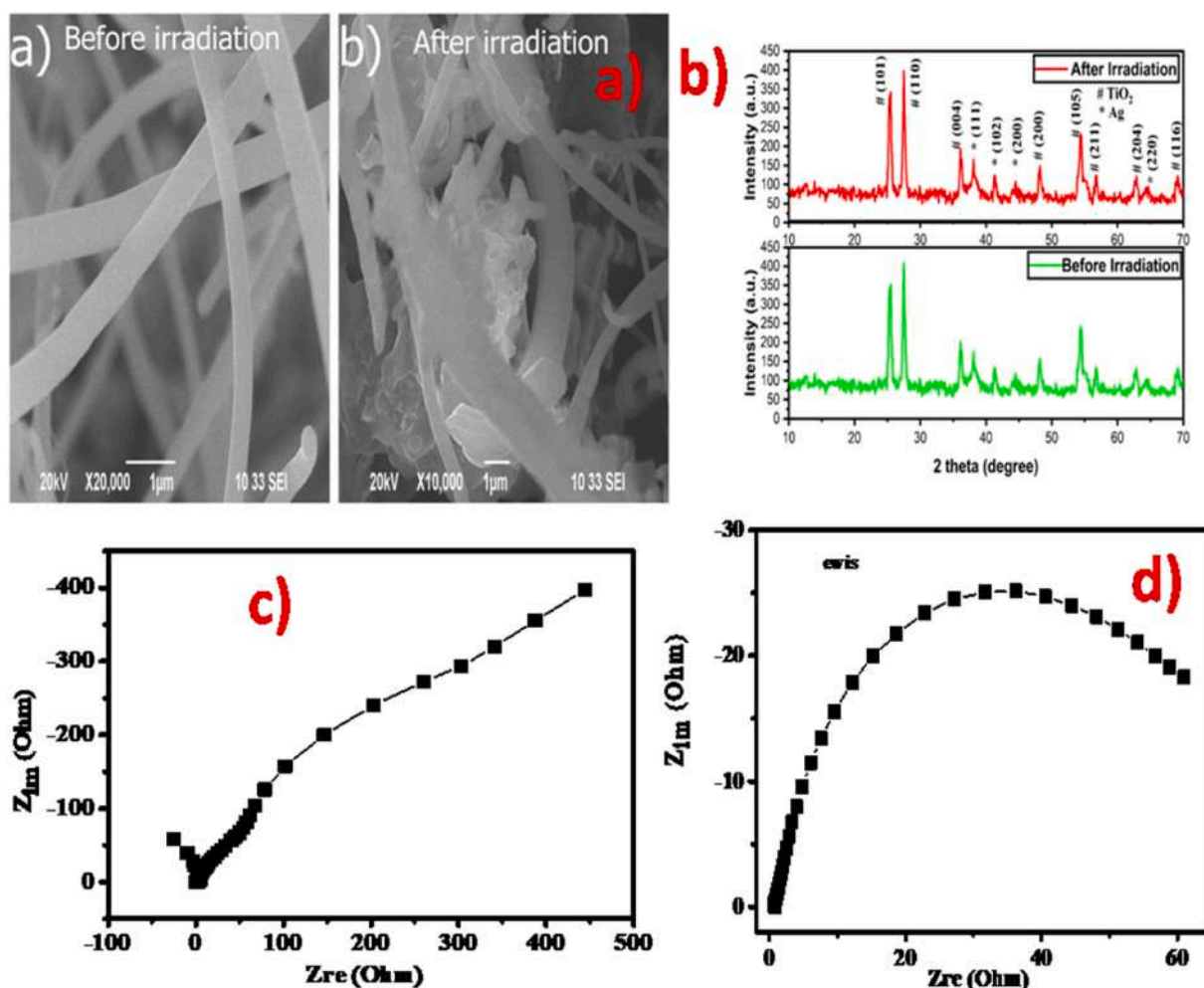
**Table 1**  
Comparison of photocatalytic performance of Ag/TiO<sub>2</sub> with reported literature.

Catalyst	Model pollutant Dye	Performance (%)	Source of light	Irradiation time (Min)	Reference
Ag/TiO <sub>2</sub>	MB	79.8	Visible	150	Zhao et al. (2017)
PS@Ag@TiO <sub>2</sub>	MB	90	Visible	30	Cha et al. (2009)
Ag <sub>2</sub> O/ZnO-TiO <sub>2</sub>	RhB	95	Visible	150	Wani and Ganie (2021)
Pristine Ag/TiO <sub>2</sub>	MO/RhB	77/84	Sunlight	180	Heng et al. (2021)
Ag/Ag <sub>2</sub> S-TiO <sub>2</sub>	CV	28.92	Sunlight	120	Shuang et al., (2018)
Ag-Ag <sub>2</sub> O/TiO <sub>2</sub> @polypyrrole	MB	83.9	UV	120	Kumar et al. (2016)
Fe <sub>3</sub> O <sub>4</sub> -TiO <sub>2</sub> -Ag	MB	90.1	Visible light	85	Ghafuri et al. (2019)
Ag <sub>2</sub> O/TiO <sub>2</sub>	MB	95.4	Visible light	180	Kavitha et al. (2021)
Fe <sub>2</sub> O <sub>3</sub> /TiO <sub>2</sub>	MB	-	UV	60	Ahmed et al. (2013)
g-CN-TiO <sub>2</sub>	MB	-	UV	-	Vijayan et al. (2023)
TiO <sub>2</sub> -GO	MG and MB	85 and 93	Visible	60	Verma et al. (2023)
SiO <sub>2</sub> -TiO <sub>2</sub>	MB	90	Visible	30	Mahanta et al. (2022)
Cu <sub>2</sub> O-CuO//TiO <sub>2</sub>	MB and MO	87	Visible	120	Ansari et al. (2022)
Fe <sub>3</sub> O <sub>4</sub> /TiO <sub>2</sub>	RhB	91	Visible	120	Madima et al. (2022)
G-TiO <sub>2</sub>	MB	-	Visible	120	Shimi et al. (2022)
Ag/TiO <sub>2</sub>	MB	94	Sunlight	120	<b>Present work</b>

**Table 2**  
Shows Zone of inhibition values of bacterial strains.

S.No	Gram positive (S. Aureus)	Gram negative (E-coli)
1.	14 mm	17 mm

exposure for five cycles. The concentration of MB dye should be constant in each cycle, and the recovered centrifuged catalyst should be used in subsequent cycles of the degradation process. The motivation remains efficient and has remarkable photo stability even after four cycles. Maximum MB dye degradation occurs after 120 min, and the efficiencies for the 1st, 2nd, 3rd, 4th, and 5th cycles are 92%, 92%, 92%, 90%, and 90%, respectively. Therefore, the results of the present investigation support the notion that Ag-TiO<sub>2</sub> nanofibers (NFs) formed during the photocatalytic degradation of MB under solar light irradiation may



**Fig. 5.** (a & b) shows Morphological and Structural stability of Ag-TiO<sub>2</sub> nanofibers (NFs) after 5 cycles and (c & d) shows EIS spectra of Ag-TiO<sub>2</sub> nanofibers (NFs).

exhibit excellent photo stability, longer life span, and photo corrosion resistance.

### 3.9. Electrochemical impedance spectroscopy

The three-electrode electrochemical analyser performed Mott-Schottky (MS) and electrochemical impedance spectroscopy (EIS). The working electrode active area was  $0.5 \text{ cm}^2$  by  $1.0 \text{ cm}^2$ . EIS was carried out using an open circuit voltage of  $0.2 \text{ V}$  and an AC voltage of  $5 \text{ mV}$  with a  $0.1 \text{ Hz}$  to  $100 \text{ kHz}$  frequency. The photo generated charge carrier separation and transfers were analysed during the catalytic process using the EIS of as-prepared activated carbon. Generally, the Nyquist plot semicircle radius represents the reaction rate at the photocatalyst surface. The reduced arc radius in the Nyquist plot (Fig. 5 c and d) suggests that surface imperfections in the produced Ag-TiO<sub>2</sub> nanofibers (NFs) may be the cause of the enhanced photoreaction and improved efficient charge transfer with decreased electrical resistance Wilke et al. (2018).

### 3.10. Antibacterial activity

Fig. 6 (a) represents the antibacterial screening of Ag-TiO<sub>2</sub> nanofibers (NFs). Agar diffusion was used to visualise the antibacterial activity of Ag-TiO<sub>2</sub> NFs. Due to their powerful antibacterial capabilities, metals and metal oxides are used to treat various bacterial illnesses. Due to their potent antibacterial activity, silver nanoparticles are

traditionally used in medication delivery, biomedical imaging, tissue engineering, and cancer treatment. Nanoparticles based on TiO<sub>2</sub> are frequently employed for many applications Prakash et al. (2016). The cell wall membrane of gram-positive bacteria is composed of thin peptidoglycan easily disrupted by nanoparticles. Positive cell walls are composed of a  $30 \text{ nm}$  thick coating of peptidoglycan that is tough to degrade. Cell wall membranes are composed of lip polysaccharides, phospholipids, and proteins. Interactions between microorganisms and nanoparticles may change permeability and induce cell death Pinto et al. (2013). The inhibitory mechanism may involve (1) photocatalyst irradiation, (2) the production of active OH groups, and (3) the bombardment of silver ions and hydroxyl radicals on the bacterial cell wall, resulting in damage and death. TiO<sub>2</sub> nanoparticles disrupt bacterial cells by interacting with the cell wall membrane. The way bacteria breathe is changed by the plasmonic ions on the surface of TiO<sub>2</sub> nanofibers that are optically active (Parvathiraja and Shailajha, 2021). The interaction of Ag<sup>+</sup> ions with gram-negative bacteria results in electrostatic attraction. Ag-NPs attach to phosphorus and sulphur in the bacterial cell membrane, as well as other intercellular components like DNA bases and proteins, disrupting bacterial function and eventual death Naseem et al. (2016). As predicted, there is no inhibition zone in control. *E. coli* produces the largest inhibitory zone of the two examined bacterial strains, measuring  $7 \text{ mm}$ , whereas *S. aureus* produces a zone of  $4 \text{ mm}$ . Changes in the zone inhibitory layer are attributable to the varying susceptibility and size of nanoparticles. The bactericidal activity of nanoparticles may result from the binding of surface to bacteria, which depends on the

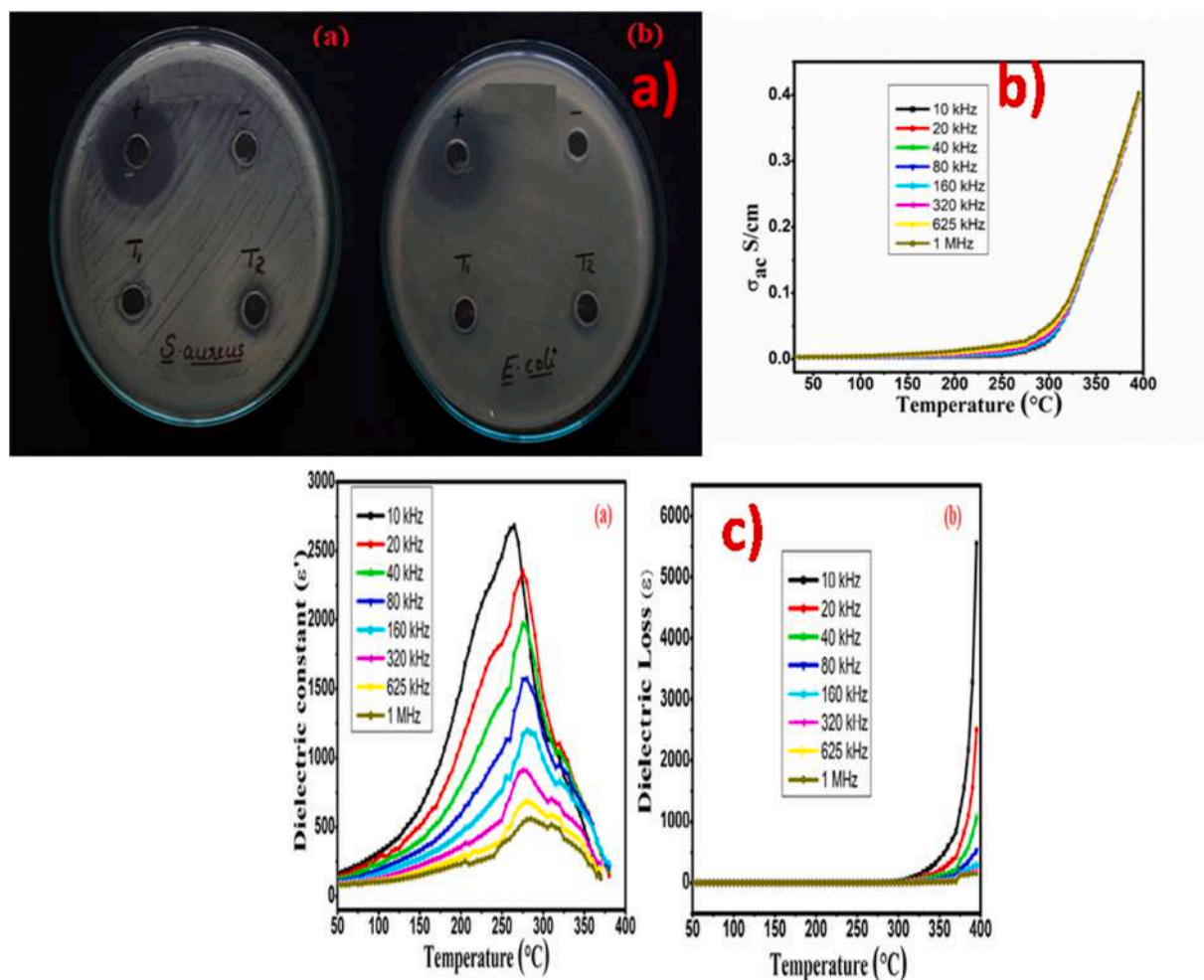


Fig. 6. a) antibacterial activity of Ag-TiO<sub>2</sub> nanofibers b) a. c conductivity spectra of Ag-TiO<sub>2</sub> nanofibers (NFs) and c) Dielectric properties of Ag-TiO<sub>2</sub> nanofibers (NFs).

amount of accessible surface area for interaction. As the particles' size rises, the surface  $O_2^-$  also concentration increases, resulting in a more efficient breakdown of the bacteria's cell wall and cytoplasmic membrane. Antibacterial activity is affected by the size and shape of the particles produced. Because of this, the nanocomposite made seems to be good for treating wastewater and biomedical uses. When compared to *Aureus* the gram negative *E-Coli* bacteria result higher zone of inhibition. Hence the prepared nanofibers are highly applicable for wood dressing and food packaging etc.

### 3.11. Dielectric properties

Fig. 6 (c) illustrate Ag-TiO<sub>2</sub> nanofibers (NFs) dielectric characteristics. Using a hydraulic pressure pellet under high pressure, the pellets were created. At various temperatures, the change in dielectric loss values is measured using frequencies ranging from 10 Hz to 1 MHz. A material's dielectric properties depend on its grain boundaries, grain size, charge carriers, charge orientations, temperature, the outside frequency, and how the experiment is done. Dielectric constant

$$\epsilon' = \frac{C_d}{\epsilon_0 A} \quad (10)$$

where,  $C_p$ -capacitance,  $t$ -thickness,  $A$ -samples' area,  $\epsilon_0$ -permittivity of free space ( $\epsilon_0 = 8.85 \times 10^{-12}$  F/m) Sharma et al. (2015).

Dielectric loss or permittivity is obtained from the value of the dissipation factor

$$D = \frac{\epsilon''}{\epsilon'} \quad (11)$$

$$\epsilon'' = D \times \epsilon' \quad (12)$$

where  $D$  is the Dissipation factor,  $\epsilon'$  is the Dielectric constant Suresh (2014).

As can be seen in Fig. 6 (c), the constant dielectric experiences an exponential decline with increasing frequency up to the point when it reaches a value that is almost constant in the high-frequency region. Results indicate that the dielectric constant values vary concerning temperature. Due to the frequency of electric charge carriers, dielectric constant values decrease with frequency; impurities, crystal flaws, and crystalline size result in greater dielectric loss factors at lower frequencies. When the quantity of nano-Ag in a composite is modest, it can be evenly dispersed to form many Coulomb islands, impeding electron transit and decreasing interfacial polarization. For higher temperatures, the space charge polarization is predominant. All four polarizations are present at low frequencies, so the dielectric constant value is high.

In contrast, these polarizations' progressive loss of significance at higher frequencies may account for their low value Jadhav and Biswas (2016). Positive and negative charges move towards the positive and negative electric field poles, respectively, when Ag-TiO<sub>2</sub> pellets are subjected to an external electric field. So, space-charge polarization happens at the Ag-TiO<sub>2</sub> surfaces, making nanocomposites with a much higher dielectric constant.

### 3.12. AC conductivity

The AC electrical conductivity were measured with different temperature. AC conductivity of Ag-TiO<sub>2</sub> nanofibers (NFs) was calculated using the formula

$$\sigma_{ac} = \omega \epsilon_0 \epsilon' \tan \delta \quad (13)$$

where  $\epsilon_0$ -permittivity of free space ( $\epsilon_0 = 8.85 \times 10^{-12}$  F/m),  $\omega$ -angular frequency. Fig. 6 (b) Illustrates the temperature-dependent AC conductivity of Ag-TiO<sub>2</sub> nanofibers (NFs). The conductivity ( $\sigma$ ) was shown to increase with increasing temperature Kumar et al. (2017). Crystalline size, grain and grain borders, surface-to-volume ratio, and

nanocomposite structure determine AC conductivity. Thus, the composite material may be used in nanodevices, optoelectronics, and spintronic.

## 4. Conclusion

Using a hydrothermal technique effectively produced Ag-TiO<sub>2</sub> nanofibers (NFs). The Ag-TiO<sub>2</sub> nanofibers (NFs) XRD pattern reveals the FCC structure of silver and the anatase phase of TiO<sub>2</sub>. From SEM investigation, nanofiber-shaped morphology was observed. The UV spectra of nanocomposites reflect their optical activity. For a 0.02 mg/mL concentration of catalyst, Ag-TiO<sub>2</sub> nanofibers (NFs) have a maximum degradation efficiency of 94%. The increase in photo-degradation efficiency may be attributable to a reduction in crystalline size, particle size,  $e^-$  and  $h^+$  recombination rates, and other factors. The antibacterial activity of Ag-TiO<sub>2</sub> nanofibers (NFs) is efficient against gram positive and gram-bacteria. So, the Ag-TiO<sub>2</sub> nanofibers (NFs) can be used in electrical, biological, and wastewater treatment applications.

### Author contribution

M.A, A.N: Writing – original draft S.A; Data curation T.S; Revising; Reviewing and Editing, A.A, R.A.A, M.S.S.M; Data Collection; M.S; Supervision.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

No data was used for the research described in the article.

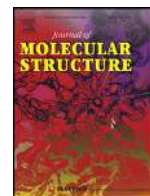
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# Structural, Hirshfeld surface analysis, third order non-linear optical and molecular modelling of imidazolium glutarate single crystals for optical applications

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## ABSTRACT

The Imidazolium glutarate (IMGA) single crystal was grown using a low-temperature solution growth method. The title crystal belongs to the triclinic crystal structure with space group P1. <sup>13</sup>C and <sup>1</sup>H nuclear magnetic resonance spectra were recorded to evaluate the environment of the title compound. The grown crystal (2 0 2) was orientated using powder X-ray diffraction (XRD) studies. The vibrational modes present in the title compound were confirmed through Fourier transform infrared (FT-IR) and FT-Raman spectral studies. The IMGA crystal is stable up to 150 °C and material weight loss occurs between 150 and 258 °C. The UV-Vis-NIR studies show that 75% transmission in the entire visible region. The crystals' dielectric loss and constant were calculated as a function of frequency. Intermolecular interactions and fingerprint plots of the IMGA were executed by the Hirshfeld Surface (HS) analysis. The theoretical non-linear optical (NLO) properties like first-order hyperpolarizability and dipole moment have been studied. The 3rd order NLO susceptibility and related parameters have been studied by Z-scan measurement.

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## 1. Introduction

Organic materials are more attractive and versatile in the field of molecular optoelectronics [1,2]. The interactions between the molecules in organic compounds provide electrical, conducting, and optical properties [3]. Organic crystals have the significant advantage of being able to be modified according to our demands in terms of material qualities and chemical structure. The molecules in the crystal structure of the imidazolium-based dicarboxylic crystals form hydrogen-bonded chains, with strong N-H...O hydrogen bonds connecting the imidazolium cations and strong O-H...O type connections connecting the carboxylate anions [4,5]. Both kinds of chains self-assemble into layers or a supramolecular network. Imidazole is a critically important nitrogen heterocycle with unique biological and NLO characteristics [6,7]. Because of its chemical structure, imidazole can act as both a weak acid and a base, it serves as a proton transfer agent in living systems. Horike et al. [8], have achieved a significant improvement in proton conductiv-

ity in a metal-organic framework (MOF)-based compound by using the proton donor-accepter capacities and rotational motions of a type of heterocyclic imidazole molecule. In addition, MacDonald et al. [9], Fuller et al. [10], and K. Pogorzelec-Glaser et al. [11] have produced anhydrous entirely organic proton conductors that are hydrogen-bonded (H-bonded). The structure of imidazolium glutarate (IMGA) and its electrical properties have been reported by Pogorzelec-Glaser et al. [11]. However, theoretical research can be useful in understanding the relationship between structure and property, which can help in the development of NLO properties. Using the Gaussian 09 w software, the molecular electrostatic potential (MEP), highest occupied molecular orbital and lowest unoccupied molecular orbital (HOMO-LUMO), hyperpolarizability, natural bond orbital (NBO) of the IMGA molecule have been determined [12]. The relationship between structure and NLO properties of imidazolium-based organic single crystals such as imidazolium hydrogen succinate [13], imidazolium L-tartrate [14], imidazolium diphenylacetate diphenylacetic acid [15] and 2ethylimidazolium D-tartrate [16] have been studied both experimental and theoretical. In this point of view, the title compound was studied both experimental (single crystal XRD, powder XRD, FT-IR, FT-Raman, etc.) and theoretical (optimized structure, HOMO-LUMO, NBO,

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Fig. 1. As grown IMGA single crystal.

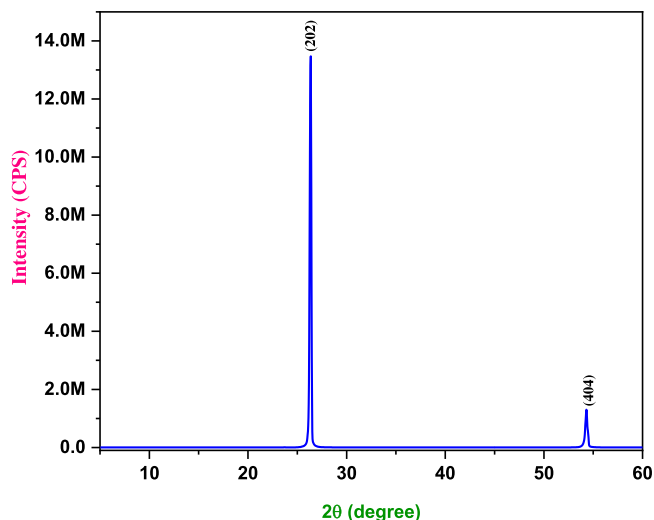


Fig. 3. Powder XRD pattern took along (1 0 1) plane of the IMGA crystal.

MEP, etc.). The obtained results are discussed in the forthcoming sessions.

## 2. Materials and methods

### 2.1. Growth of IMGA crystal

IMGA was synthesized by the reaction between imidazole (6.808 g, Merck) and glutaric acid (13.212 g, Loba chemical) taken in a 1:1 ratio. The calculated amount of glutaric acid was slowly added to a saturated aqueous solution of equimolar imidazole at room temperature to prepare the growth solution. A magnetic stirrer was used to thoroughly agitate the supersaturated solution for three hours at room temperature, producing a homogeneous mixing of the solution. Then the solution was filtered twice using a Whatman filter paper and put into a beaker covered with a thin polythene cover to reduce the rate of evaporation. Tiny crystals have been formed on the bottom of the beaker due to spontaneous nucleation. The purity and size of the crystal were improved by two times recrystallization processes. After 30 days, an optically

transparent good quality IMGA crystal of size  $15 \times 10 \times 2.5$  mm<sup>3</sup> was obtained. Fig. 1 shows the as-grown crystal of IMGA.

### 2.2. Computational details

The Hirshfeld surface and related fingerprint analysis were performed by CRYSTAL EXPLORER 3.1 [17]. The Gaussian 09 W programme has been used to do the quantum chemical computation (gas phase) of the IMGA using the Becke-3-Lee-Yang-Parr (B3LYP) level of theory [18] supplemented with the standard 6-311++G(d,p) basis set [19,20]. The GAUSSIAN 09 W package was used to determine the geometrical parameters, including energy, band gap, bond angle, dihedral angle, and atomic charges of the title molecule. The Gauss View 5.0 application [21] was used to display the optimized geometry. As a result, the B3LYP/6-311++G(d,p) basis set was used to generate the Mulliken atomic charge (MAC) distribution, HOMO-LUMO, MEP, and first-order hyperpolarizability, which were then viewed using the Gauss View 5.0 program. The title molecule's NBO analysis was computed using the NBO 3.1 programme [22].

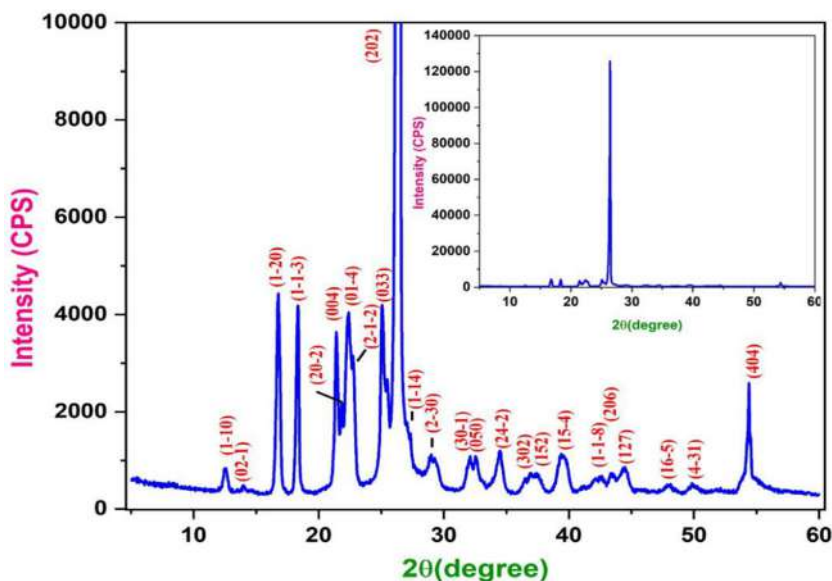


Fig. 2. Enlarged powder XRD pattern and observed powder XRD pattern of IMGA crystal.

**Table 1**  
Observed lattice parameters of IMG A crystal.

Parameters	Single Crystal XRD (Present study)	Reported Data [7]
Crystal structure	Triclinic	Triclinic
a	8.34 Å ± 0.05	8.420 Å (2)
b	13.56 Å ± 0.08	13.685 Å (3)
c	16.97 Å ± 0.09	17.068 Å (3)
α	90.53° ± 0.09	90.62° (3)
β	103.59° ± 0.20	103.45° (3)
γ	91.17° ± 0.14	91.03° (3)
Volume (Å <sup>3</sup> )	1890 ± 30	1912.2 (7)

### 3. Result and discussions

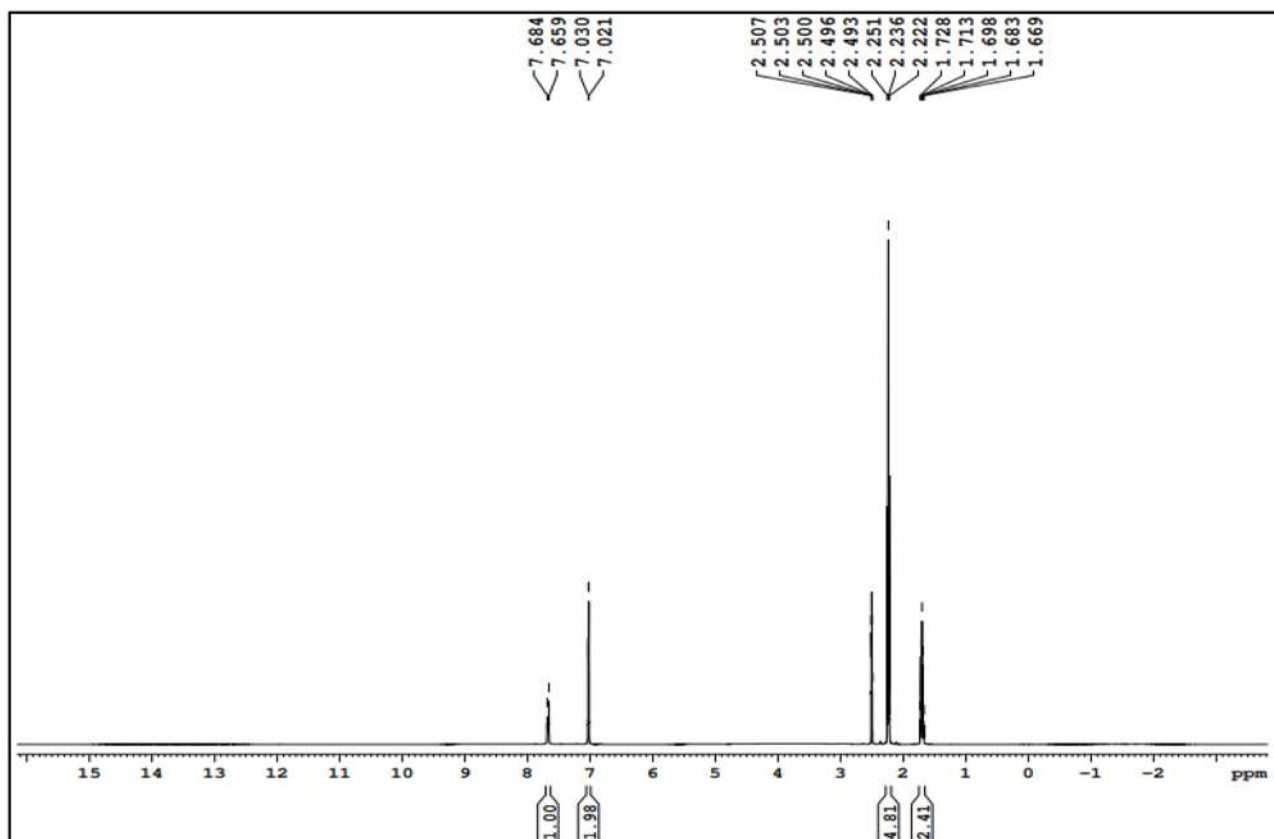
#### 3.1. X-ray diffraction (XRD) analysis

The IMG A crystal was subjected to single crystal X-ray diffraction (SCXRD) technique using SAINT (APEX II) and SHELXTL software for frame Integration and structure solution and refinement, respectively. It reveals that IMG A crystallizes in the triclinic system with space group P1. The observed lattice parameters (Cell lengths, angles, and volume) are given in Table 1. It is in good agreement with the reported data [11]. The powder and as-grown IMG A crystal were subjected to powder XRD (PXRD) analysis using the Empyrean X-ray Diffractometer technique. The observed PXRD pattern of powdered IMG A is shown in Fig. 2. This figure shows that (202) plane intensity is very high (~128,000 CPS) compared to other planes. The sharp high intensity plane indicates the crystalline quality is good. The enlarged PXRD pattern and indexed (hkl) planes of IMG A crystal are shown in Fig. 2.

Basically, the crystals are anisotropic in nature, it gives different optical and electrical parameters for different planes or directions. In this point of view, the grown crystal top surface plane was identified using the same PXRD configuration. The PXRD diffraction pattern of the (101) plane of IMG A crystal is shown in Fig. 3. The crystal's PXRD intensity is very high compared to the powdered sample's PXRD intensity. Fig. 3 indicates the order of (101) planes such as (202) and (404) planes and the corresponding 2θ values are 26.36° and 54.35°, respectively. The observed planes and 2θ values (Fig. 3) are well-matched in powder sample XRD lower angle 2θ values (Fig. 2).

#### 3.2. FT-NMR studies

The <sup>1</sup>H NMR (500.23 MHz) and <sup>13</sup>C NMR (125.78 MHz) spectra of the IMG A crystal were recorded using a 500 MHz FT NMR Spectrometer (BRUKER AVIII 500) in DMSO as solvent. The <sup>1</sup>H and <sup>13</sup>C NMR spectra show the signals due to various protons and carbons as shown in Figs. 4 and 5, respectively. Fig. 4, the strong signal due to imidazolium ring two symmetric protons appears in the region at 7.02 to 7.03 ppm. The COOH proton occurs at 7.659 ppm. The -CH protons in the glutarate moiety appear in the region of 1.72 to 2.25 ppm [23]. Fig. 5, the two symmetric -CH carbon present of the imidazolium moiety, which causes the signal at 122.06 ppm. The peak at 135.58 ppm occurs in the spectra due to the peak for -CH carbon, which is located between two NH groups of the imidazolium moiety [24]. The peak at 174.5 ppm occurs in the spectra due to the two symmetric carbonyl carbon presence of glutarate moiety. The presence of other protons and carbons is given in Table 2. Between two NH groups of the imidazolium



**Fig. 4.** <sup>1</sup>H NMR spectrum of IMG A crystal.



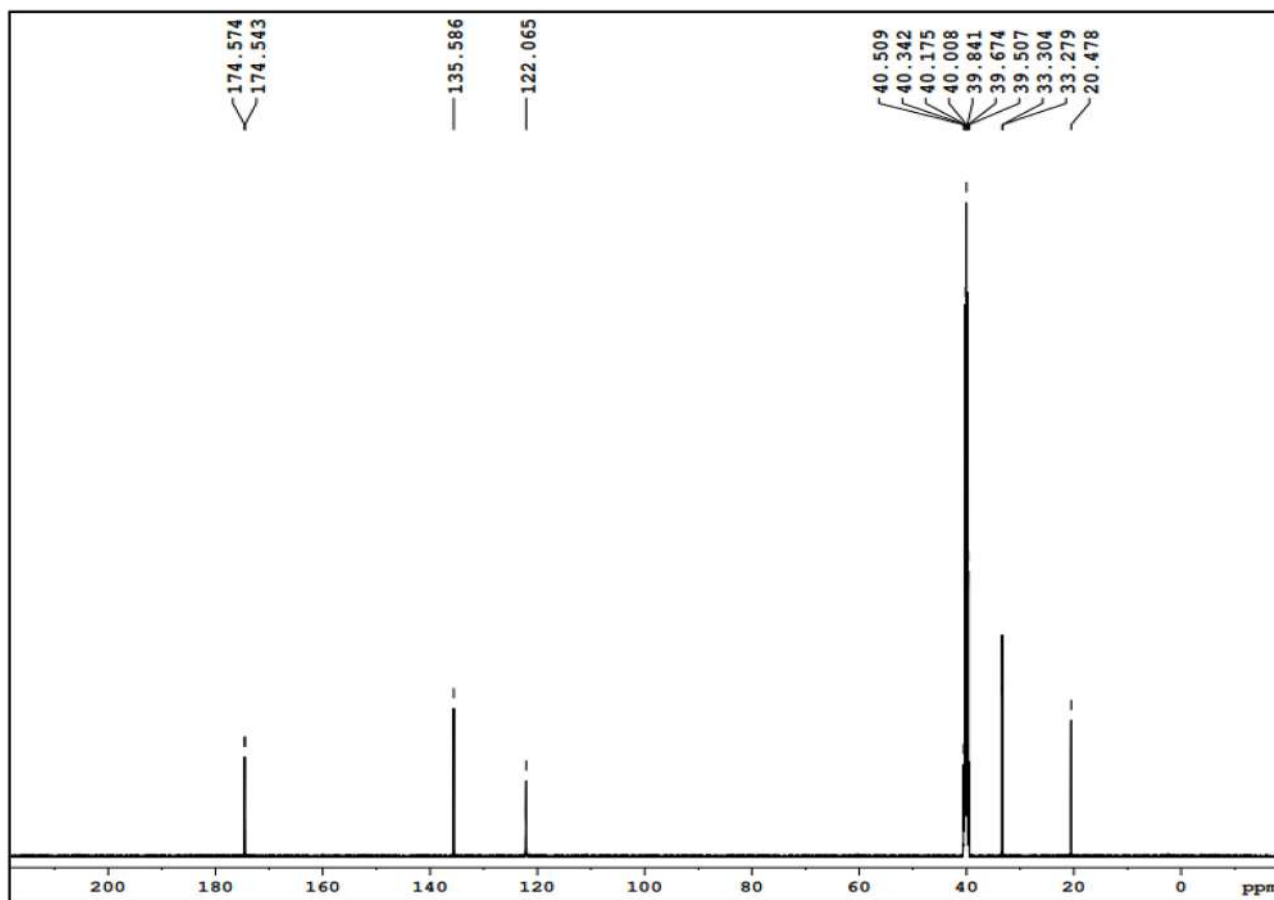


Fig. 5.  $^{13}\text{C}$  NMR spectrum of IMGa crystal.

**Table 2**  
Experimental  $^1\text{H}$  &  $^{13}\text{C}$  NMR chemical shift of IMGa crystal.

Atoms	$^{13}\text{C}$ NMR (ppm)	Atoms	$^1\text{H}$ NMR (ppm)
5C	20.478	10H	2.251
6C	33.279	11H	1.698
7C	174.543	12H	2.236
8C	20.478	13H	1.713
9C	33.304	14H	2.222
19C	135.586	15H	1.728
20C	122.065	16H	7.659
21C	122.065	22H	7.030
		23H	1.683
		24H	7.684
		25H	7.021
		26H	1.669

moiety, there is a peak for  $-\text{CH}$  carbon, which is what causes the peak at 135.58 ppm.

### 3.3. FTIR and FT-Raman studies

The recorded FTIR and FT-Raman spectrum of the IMGa compound are shown in Figs. 6 and 7, respectively. The standard organic spectroscopy literature is used to assign the observed vibrational modes [25,26]. Table 3 lists the IMGa compound's observed vibrational modes and assignments. The  $\text{O}-\text{H}$  bending modes (in the plane and out of the plane) of the carboxylic acid group [27] are observed at 1412 and 911  $\text{cm}^{-1}$  in FTIR and 1420 and 910  $\text{cm}^{-1}$  in FT-Raman, respectively. The aromatic  $\text{C}-\text{H}$  bending modes (in the plane and out of plane) of the imidazole ring are observed at 1095 and 775  $\text{cm}^{-1}$  in FTIR and

1094 and 775  $\text{cm}^{-1}$  in FT-Raman, respectively. The presence of the  $\text{NH}^+$  stretching mode of the tertiary amine salt is responsible for the peak at 2970  $\text{cm}^{-1}$  in FTIR and 2930  $\text{cm}^{-1}$  in FT-Raman. The presence of  $\text{COO}^-$  asymmetric and symmetric stretching modes of the carboxylate group are responsible for the peaks at 1680 and 1315  $\text{cm}^{-1}$  in FTIR and 1685 and 1302  $\text{cm}^{-1}$  in FT-Raman, respectively. The formation of the title compound's molecular structure reveals the existence of an amine salt ( $\text{NH}^+$ ) and a carboxylate group ( $\text{COO}^-$ ). Herewith the important vibrational modes are discussed, and the other vibrational modes are given in Table 3.

### 3.4. Hirshfeld surface (HS) analysis

The idea behind HS came from an effort to define the area a molecule takes up in a crystal to divide the crystal's electron density into molecular units of electron density. The two distances  $d_i$ , the distance from the HS to the closest nucleus inside the surface, and  $d_e$ , the distance from the HS to the closest nucleus outside the surface on HS, were compared to create fingerprint plots [28,29]. The  $d_{\text{norm}}$  surface exhibits either negative or positive values, when compared to the total of the van der Waals radii, depending on the length of intermolecular interaction. The SCXRD data (CIF file) were subjected to HS analysis using Crystal Explorer 3.1 [30]. Fig. 8a and b display the HS plotted over the  $d_i$  and  $d_e$  properties in the range of 0.569 Å (red) to 2.343 Å (blue) and 0.571 Å (red) to 2.380 Å (blue), respectively. Fig. 8c displays the HS plotted over the  $d_{\text{norm}}$  property in the range of  $-0.861$  Å (red) to 1.063 Å (blue). Intermolecular interactions (IMIs) are shown through colour coding. Intermolecular interactions with distances

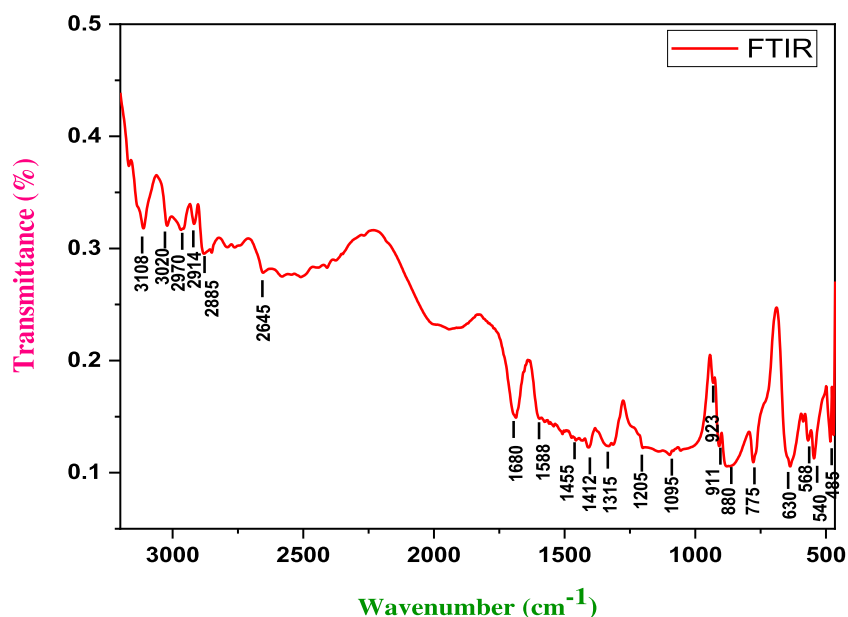


Fig. 6. FT-IR Spectrum of IMGa crystal.

Table 3  
FTIR and FT-Raman vibrational assignment of IMGa crystal.

Wavenumber (cm <sup>-1</sup> )		Mode of vibrations	Assignments
FTIR	FT-Raman		
3108	-	N-H stretching	Presence of amine group
3020	-	Aromatic C-H stretching	Presence of imidazole ring
2970	2930	NH <sup>+</sup> stretching	Presence of tertiary amine salt
2914	-	C-H stretching	Presence of tertiary C-H group
2885	2885	C = O stretching	Presence of carboxylic acid group
1680	1685	COO <sup>-</sup> asymmetric stretching	Presence of carboxylate group
1588	1590	C-N stretching	Presence of imidazole ring
1455	1450	N-H in plane bending	Presence of amine group
1412	1420	C-O stretching and O-H in plane bending (coupled)	Presence of carboxylic acid group
1315	1302	COO <sup>-</sup> symmetric stretching	Presence of carboxylate group
1205	1230	C-O stretching	Presence of hydroxyl group
1095	1094	Aromatic C-H in plane bending	Presence of imidazole group
911	910	O-H in plane bending	Presence of carboxylic acid group
775	775	Aromatic C-H out of plane bending	Presence of imidazole group
630	630	O-H out of plane bending	Presence of hydroxyl group

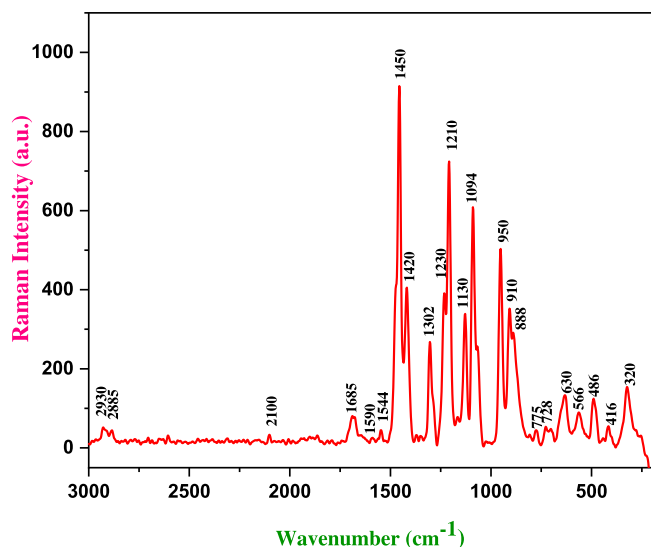


Fig. 7. FT-Raman Spectrum of IMGa crystal.

smaller than, equal to, and greater than van der Waal radii are indicated by the red, white, and blue marks, respectively [31,32]. Large circular depressions (deep red) that are suggestive of hydrogen bonding connections can be seen on the  $d_{\text{norm}}$  surfaces, while additional visible spots are caused by H $\cdots$ H contacts. HS plots of the hydroxyl O-H and carbonyl O atom in 1 may be seen as the bright red area in Fig. 8c indicating the dominant interactions between these two atoms. C-H $\cdots$ O interactions are the cause of the title compounds' light red spots. For each interatomic contact and all interactions, 2D fingerprint plots are generated. When calculating individual interatomic distances, contacts, as well as each interatomic contact's reciprocal contact.

The 2D fingerprint plot for overall interactions is shown in Fig. 9. The dominant IMIs of the total HS for IMGa molecule are H $\cdots$ H (36.6%) interactions. For each molecule, the proportions of O $\cdots$ H and H $\cdots$ O interactions contribute 52.1% of the total HS. The other IMIs are given in Fig. 9. Fig. 8d and e display the HS plotted over the shape index and curvedness surfaces. The curvedness surface clearly shows a flat zone toward the bottom of both sides of the molecules, indicating the presence of  $\pi$ - $\pi$  stacking [33]. On the surface, this feature looks like a rather flat green area with extremely comparable contact distances.

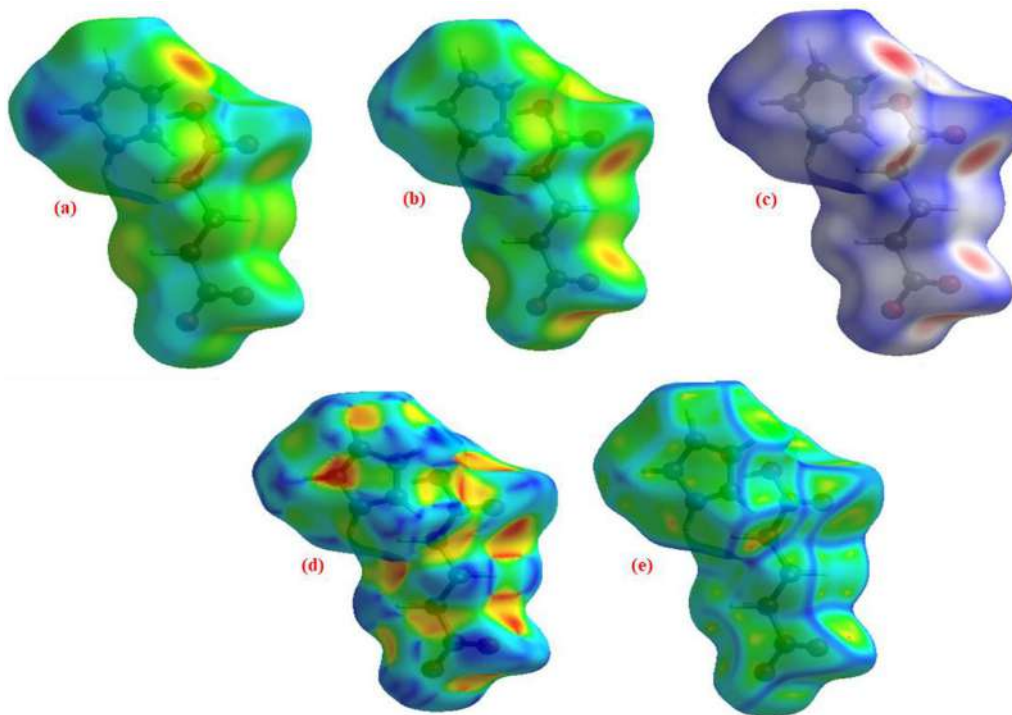


Fig. 8. 3D Hirshfeld surfaces of IMGA molecule (a)  $d_i$  (b)  $d_e$  (c)  $d_{norm}$  (d) Shape index and (e) Curvedness.

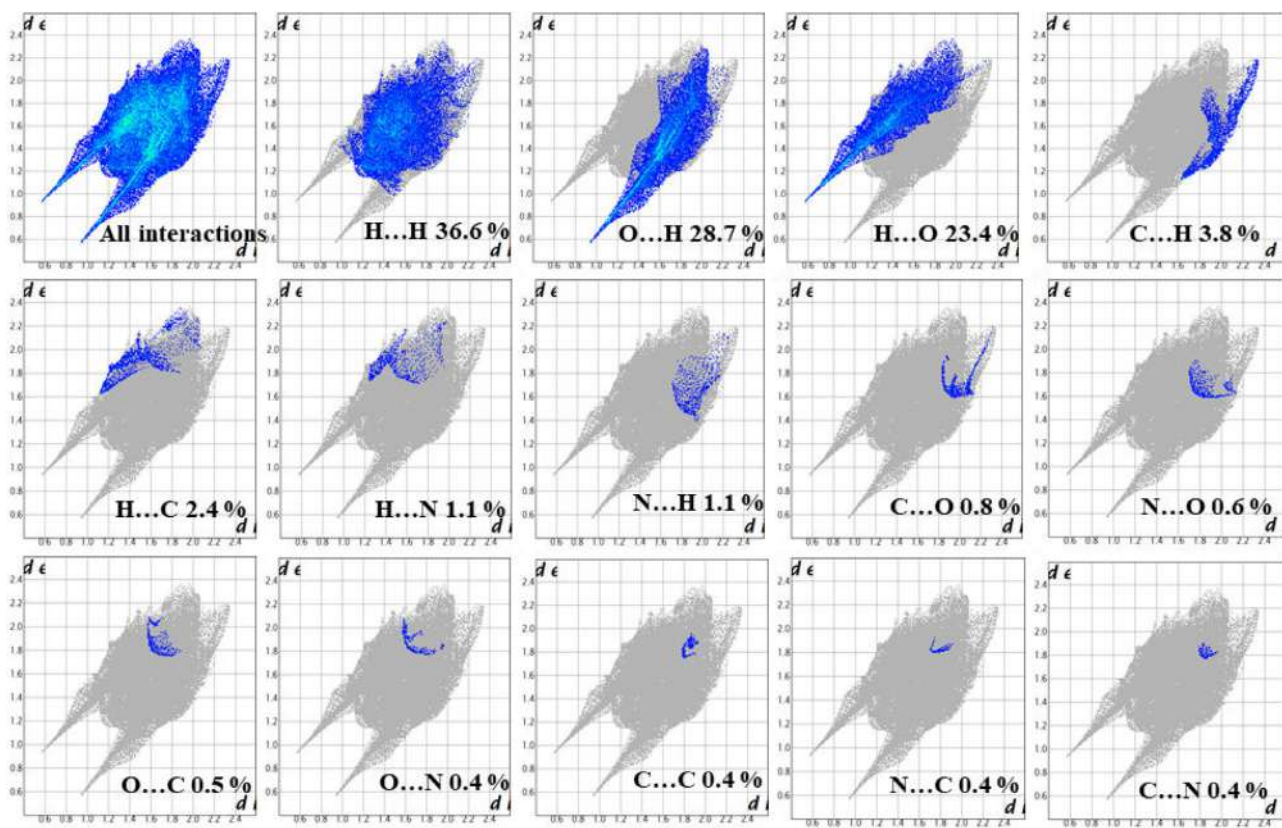


Fig. 9. 2d fingerprints plots of IMGA molecule.

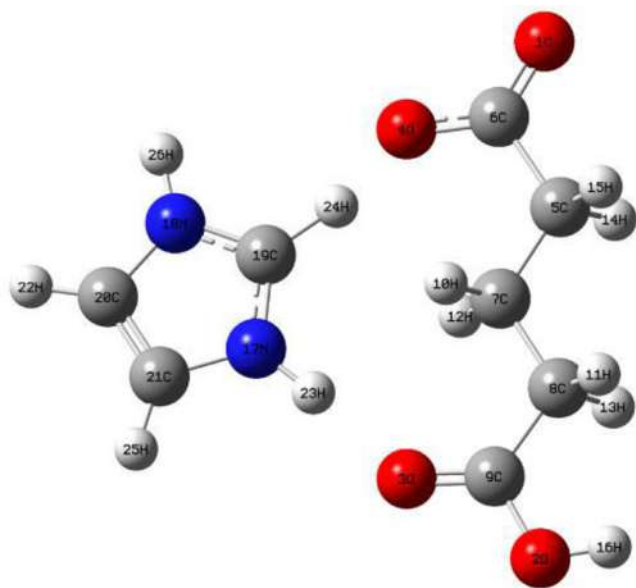


Fig. 10. Optimized structure of IMGa molecule.

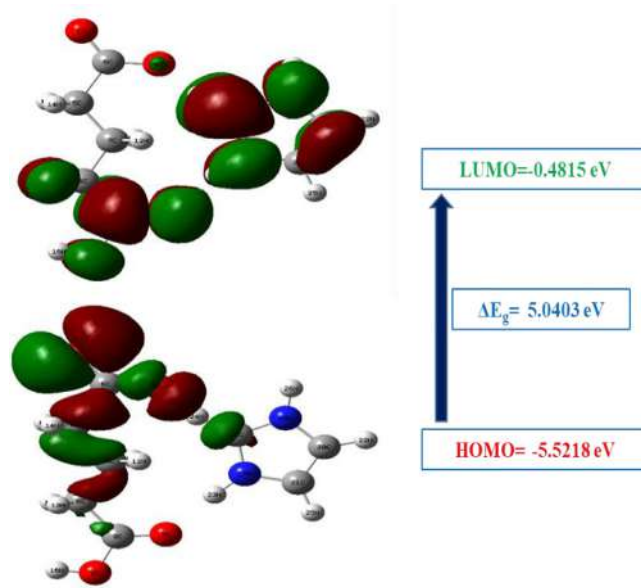


Fig. 11. HOMO-LUMO energy diagram of IMGa molecule.

### 3.5. Optimal geometry analysis

Fig. 10 displays the IMGa's optimal geometry as computed by the B3LYP approach with atom numbering. Table 4 shows the optimized bond lengths and bond angles of the IMGa compound as determined using ab-initio DFT(B3LYP) technique using the 6-311++G(d,p) basis set. The majority of the optimal bond lengths in Table 4 are slightly longer than the experimental values. Because the actual results are based on molecules in the solid state and the theoretical calculations are based on isolated molecules in the solid phase [34].

The optimized C–C bond lengths for IMGa using DFT/B3LYP fall in the range of 1.362–1.532 Å, while the experimental C–C bond lengths fall in the range of 1.361–1.562 Å. The C<sub>19</sub>–N<sub>17</sub> and C<sub>21</sub>–N<sub>17</sub> bond lengths in the imidazole ring are found to be varied from 1.3408 to 1.3842 Å in B3LYP, demonstrating that the boundary between single and double bonds inside the ring is present due to electron conjugation. The C–H bond lengths determined from the theoretical values range between 1.097 and 1.099 Å, while the experimental value is between 0.955 and 0.990 Å. This greater variation in C–H bond lengths may be brought on by the X-ray diffraction studies' low scattering coefficients for hydrogen atoms, which are not taken into account in theoretical models [35]. All the C–C–C bond angles (C<sub>7</sub>–C<sub>8</sub>–C<sub>9</sub>, C<sub>5</sub>–C<sub>7</sub>–C<sub>8</sub>, and C<sub>6</sub>–C<sub>5</sub>–C<sub>7</sub>) in glutarate are around 114° in the experimental and 115° in B3LYP. The angles of C<sub>19</sub>–N<sub>18</sub>–C<sub>20</sub> and C<sub>19</sub>–N<sub>17</sub>–C<sub>21</sub> are 111.082° and 110.755° in B3LYP and 109.15° and 109.28° in experimental, respectively. Herewith the important optimized structural parameters are discussed and other structural parameters are given in Table 4.

### 3.6. Frontier molecular orbitals

Understanding the electrical and optical properties of organic molecules depends heavily on the study of frontier molecular orbitals [36,37]. The stabilization of the bonding molecular orbital increases with an increase in the overlap of the two orbitals. In a similar vein, the antibonding's instability also increases [38]. The HOMO and LUMO orbitals, which combine to form one orbital, are two significant orbitals that are involved in molecule interaction. Using the B3LYP/6-311++G(d,p) level to determine the HOMO-LUMO energy gap of IMGa, it was found that the energy gap rep-

resents the chemical activity of the molecule. The ability to receive an electron is represented by LUMO as an electron acceptor, and the ability to give an electron is represented by HOMO. Fig. 11 depicts the distributions and energy levels of the HOMO and LUMO orbitals for the gas phase IMGa molecule. The imidazole ring and half of the glutarate portion are where the charge density is primarily accumulated. But in the case of the LUMO, more charge density moves to the glutarate moiety. The computed HOMO-LUMO energy gap  $\Delta E_g$  is 5.0403 eV. The GCRD properties such as electronegativity ( $\chi$ ), chemical potential ( $\mu$ ), global hardness ( $\eta$ ), electrophilicity index ( $\omega$ ) formulas, and calculated values are given in Table 5. The quantitative structure-property, structure-activity/toxicity analysis uses the global chemical reactivity descriptor (GCRD) values to determine chemical reactivity and permanence [39].

### 3.7. Mulliken atomic charges

Applying DFT calculations to molecular systems, the determination of atomic charges is crucial [40]. The Mulliken atomic charges (MAC) of a single IMGa molecule are computed using the B3LYP level of theory and the 6-311++G(d,p) basis set. Table 6 displays the MAC on the constituent atoms of the IMGa molecule. The carbon atoms C<sub>19</sub>, C<sub>20</sub>, and C<sub>21</sub> are positive within the imidazole ring due to the attraction of the electronegative nitrogen atom. In Fig. 12, the carbon atoms C<sub>6</sub>, and C<sub>9</sub> are positive within the glutarate moiety, whereas other carbon atoms are negative. This is caused by the electronegative oxygen atom, which attracts the positive charge from the carbon atoms. All of the hydrogen atoms have a net positive charge, as seen in Table 6. Additionally, MACs indicate that the N–H group of hydrogen atoms, which is connected to an N atom, has a larger positive atomic charge than the other hydrogen atoms. This is caused by the electronegative nitrogen atom, which attracts the positive charge from the hydrogen atoms [41].

### 3.8. Molecular electrostatic potential (MEP) analysis

For studying and predicting molecular reactive behaviour, the electrostatic potential formed in the area around a molecule by its nuclei and electrons (considered as static distributions of charge)

**Table 4**  
Optimized geometric parameters of IMGA molecule.

Bond Length	Cal. Values (Å)	Exp. Values (Å)	Bond Angle	Cal. Values (°)	Exp. Values (°)	Dihedral Angle	Cal. Values (°)	Exp. Values (°)
O <sub>1</sub> -C <sub>6</sub>	1.231	1.274	C <sub>9</sub> -O <sub>2</sub> -H <sub>16</sub>	110.017	112.90	H <sub>16</sub> -O <sub>2</sub> -C <sub>9</sub> -O <sub>3</sub>	-179.994	179.52
O <sub>2</sub> -C <sub>9</sub>	1.349	1.295	C <sub>9</sub> -O <sub>3</sub> ...H <sub>23</sub>	135.590	135.39	H <sub>16</sub> -O <sub>2</sub> -C <sub>9</sub> -C <sub>8</sub>	0.0066	-0.47
O <sub>2</sub> -H <sub>16</sub>	0.968	1.042	C <sub>6</sub> -O <sub>4</sub> ...H <sub>24</sub>	138.063	135.44	H <sub>23</sub> -O <sub>3</sub> -C <sub>9</sub> -O <sub>2</sub>	180.029	176.70
O <sub>3</sub> -C <sub>9</sub>	1.217	1.229	C <sub>6</sub> -C <sub>5</sub> -C <sub>7</sub>	115.197	114.12	H <sub>23</sub> -O <sub>3</sub> -C <sub>9</sub> -C <sub>8</sub>	0.028	-2.28
O <sub>3</sub> ...H <sub>23</sub>	1.810	1.878	C <sub>6</sub> -C <sub>5</sub> -H <sub>14</sub>	107.264	106.12	C <sub>9</sub> -O <sub>3</sub> -H <sub>23</sub> -N <sub>17</sub>	179.959	-161.28
O <sub>4</sub> -C <sub>6</sub>	1.288	1.247	C <sub>6</sub> -C <sub>5</sub> -H <sub>15</sub>	107.264	105.40	H <sub>2</sub> -O <sub>4</sub> -C <sub>6</sub> -O <sub>1</sub>	-179.999	-178.70
O <sub>4</sub> ...H <sub>24</sub>	1.442	2.250	C <sub>7</sub> -C <sub>5</sub> -H <sub>14</sub>	110.891	111.74	H <sub>24</sub> -O <sub>4</sub> -C <sub>6</sub> -C <sub>5</sub>	0.0017	-1.34
C <sub>5</sub> -C <sub>6</sub>	1.562	1.510	C <sub>7</sub> -C <sub>5</sub> -H <sub>15</sub>	110.894	109.83	C <sub>6</sub> -O <sub>4</sub> -H <sub>24</sub> ...C <sub>19</sub>	179.998	169.55
C <sub>5</sub> -C <sub>7</sub>	1.525	1.531	H <sub>14</sub> -C <sub>5</sub> -H <sub>15</sub>	105.901	107.31	C <sub>7</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>1</sub>	179.984	-172.64
C <sub>5</sub> -H <sub>17</sub>	1.097	1.095	O <sub>1</sub> -C <sub>6</sub> -C <sub>4</sub>	126.760	122.26	C <sub>7</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>4</sub>	-0.0165	6.58
C <sub>5</sub> -H <sub>15</sub>	1.097	0.990	O <sub>1</sub> -C <sub>6</sub> -C <sub>5</sub>	116.386	116.90	H <sub>14</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>1</sub>	-56.713	-47.95
C <sub>7</sub> -C <sub>8</sub>	1.527	1.515	O <sub>4</sub> -C <sub>6</sub> -C <sub>5</sub>	116.852	120.83	H <sub>14</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>4</sub>	123.285	131.27
C <sub>7</sub> -H <sub>10</sub>	1.0951	0.993	C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub>	115.451	114.73	H <sub>15</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>1</sub>	56.679	65.69
C <sub>7</sub> -H <sub>12</sub>	1.0951	0.989	C <sub>5</sub> -C <sub>7</sub> -H <sub>10</sub>	108.769	108.65	H <sub>15</sub> -C <sub>5</sub> -C <sub>6</sub> -O <sub>4</sub>	-123.322	-115.09
C <sub>8</sub> -C <sub>9</sub>	1.5189	1.511	C <sub>5</sub> -C <sub>7</sub> -H <sub>12</sub>	108.765	113.02	C <sub>6</sub> -C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub>	179.998	176.24
C <sub>8</sub> -H <sub>11</sub>	1.0997	0.954	C <sub>8</sub> -C <sub>7</sub> -H <sub>10</sub>	108.352	108.55	C <sub>6</sub> -C <sub>5</sub> -C <sub>7</sub> -H <sub>10</sub>	-57.994	-64.64
C <sub>8</sub> -H <sub>13</sub>	1.0997	1.008	C <sub>8</sub> -C <sub>7</sub> -H <sub>12</sub>	108.349	109.27	C <sub>6</sub> -C <sub>5</sub> -C <sub>7</sub> -H <sub>12</sub>	57.997	53.26
N <sub>17</sub> -C <sub>19</sub>	1.3408	1.324	H <sub>10</sub> -C <sub>7</sub> -H <sub>12</sub>	106.821	106.44	H <sub>14</sub> -C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub>	58.680	58.683
N <sub>17</sub> -C <sub>21</sub>	1.3842	1.369	C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub>	115.914	114.33	H <sub>14</sub> -C <sub>5</sub> -C <sub>7</sub> -C <sub>10</sub>	-179.313	173.61
N <sub>17</sub> -H <sub>23</sub>	1.0308	0.930	C <sub>7</sub> -C <sub>8</sub> -H <sub>11</sub>	111.033	110.77	H <sub>14</sub> -C <sub>5</sub> -C <sub>7</sub> -H <sub>12</sub>	-63.32	-68.45
N <sub>18</sub> -C <sub>19</sub>	1.3445	1.305	C <sub>7</sub> -C <sub>8</sub> -H <sub>13</sub>	111.030	108.32	H <sub>15</sub> -C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub>	-58.682	-64.48
N <sub>18</sub> -C <sub>20</sub>	1.3862	1.362	C <sub>9</sub> -C <sub>8</sub> -H <sub>11</sub>	107.854	108.35	H <sub>15</sub> -C <sub>5</sub> -C <sub>7</sub> -H <sub>10</sub>	63.324	54.64
N <sub>18</sub> -H <sub>26</sub>	1.0102	0.972	C <sub>9</sub> -C <sub>8</sub> -H <sub>13</sub>	107.852	108.08	H <sub>15</sub> -C <sub>5</sub> -C <sub>7</sub> -H <sub>12</sub>	179.317	172.54
C <sub>19</sub> -H <sub>24</sub>	1.1859	0.986	H <sub>11</sub> -C <sub>8</sub> -H <sub>13</sub>	105.831	105.51	C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub>	180.002	173.16
C <sub>20</sub> -C <sub>21</sub>	1.3611	1.362	O <sub>2</sub> -C <sub>9</sub> -O <sub>3</sub>	118.148	120.16	C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>11</sub>	58.720	49.65
C <sub>20</sub> -H <sub>22</sub>	1.0775	0.916	O <sub>2</sub> -C <sub>9</sub> -C <sub>8</sub>	116.475	115.85	C <sub>5</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>13</sub>	-58.73	-65.61
C <sub>21</sub> -H <sub>25</sub>	1.0776	0.905	O <sub>3</sub> -C <sub>9</sub> -C <sub>8</sub>	125.376	123.99	H <sub>10</sub> -C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub>	57.767	53.97
			C <sub>19</sub> -N <sub>17</sub> -C <sub>21</sub>	110.755	109.28	H <sub>10</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>11</sub>	-63.510	-69.53
			C <sub>19</sub> -N <sub>17</sub> -H <sub>23</sub>	123.684	122.74	H <sub>10</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>13</sub>	179.039	175.20
			C <sub>21</sub> -N <sub>17</sub> -H <sub>2</sub> 3	125.560	127.97	H <sub>12</sub> -C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub>	-57.779	-61.72
			C <sub>19</sub> -N <sub>18</sub> -C <sub>20</sub>	111.082	109.15	H <sub>12</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>11</sub>	-179.057	174.78
			C <sub>19</sub> -N <sub>18</sub> -H <sub>26</sub>	122.295	127.61	H <sub>12</sub> -C <sub>7</sub> -C <sub>8</sub> -H <sub>13</sub>	63.493	59.51
			C <sub>20</sub> -N <sub>18</sub> -H <sub>26</sub>	126.622	123.24	C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>2</sub>	-179.992	-176.71
			N <sub>17</sub> -C <sub>19</sub> -N <sub>18</sub>	105.569	108.06	C <sub>7</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>3</sub>	0.0083	2.30
			N <sub>17</sub> -C <sub>19</sub> -H <sub>24</sub>	129.823	125.60	H <sub>11</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>2</sub>	-56.930	-51.94
			N <sub>18</sub> -C <sub>19</sub> -H <sub>24</sub>	124.607	126.04	H <sub>11</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>3</sub>	123.070	127.07
			N <sub>18</sub> -C <sub>20</sub> -C <sub>21</sub>	105.867	107.26	H <sub>13</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>2</sub>	56.951	61.94
			N <sub>18</sub> -C <sub>20</sub> -H <sub>22</sub>	122.898	126.21	H <sub>13</sub> -C <sub>8</sub> -C <sub>9</sub> -O <sub>3</sub>	-123.048	-119.05
			C <sub>21</sub> -C <sub>20</sub> -H <sub>22</sub>	131.234	126.55	C <sub>21</sub> -N <sub>17</sub> -C <sub>19</sub> -N <sub>18</sub>	-0.003	-0.32
			N <sub>17</sub> -C <sub>21</sub> -C <sub>20</sub>	106.725	106.24	C <sub>21</sub> -N <sub>17</sub> -C <sub>19</sub> -H <sub>24</sub>	-179.977	173.76
			N <sub>17</sub> -C <sub>21</sub> -H <sub>25</sub>	122.409	117.87	H <sub>23</sub> -N <sub>17</sub> -C <sub>19</sub> -N <sub>18</sub>	180.008	179.01
			C <sub>20</sub> -C <sub>21</sub> -H <sub>25</sub>	130.865	135.71	H <sub>23</sub> -N <sub>17</sub> -C <sub>19</sub> -H <sub>24</sub>	0.034	-6.92
			O <sub>3</sub> ...H <sub>23</sub> -N <sub>17</sub>	174.973	168.34	C <sub>19</sub> -N <sub>17</sub> -C <sub>21</sub> -C <sub>20</sub>	0.003	0.53
			O <sub>4</sub> ...H <sub>24</sub> -C <sub>19</sub>	166.077	173.27	C <sub>19</sub> -N <sub>17</sub> -C <sub>21</sub> -H <sub>25</sub>	179.999	176.46
						H <sub>23</sub> -N <sub>17</sub> -C <sub>21</sub> -C <sub>20</sub>	-180.009	-178.75
						H <sub>23</sub> -N <sub>17</sub> -C <sub>21</sub> -H <sub>25</sub>	-0.012	-2.82
						C <sub>19</sub> -N <sub>17</sub> -H <sub>23</sub> ...O <sub>3</sub>	-180.019	167.39
						C <sub>21</sub> -N <sub>17</sub> -H <sub>23</sub> ...O <sub>3</sub>	-0.005	-13.41
						C <sub>20</sub> -N <sub>18</sub> -C <sub>19</sub> -N <sub>17</sub>	0.002	-0.03
						C <sub>20</sub> -N <sub>18</sub> -C <sub>19</sub> -H <sub>24</sub>	179.977	174.07
						H <sub>26</sub> -N <sub>18</sub> -C <sub>19</sub> -N <sub>17</sub>	179.998	179.76
						H <sub>26</sub> -N <sub>18</sub> -C <sub>19</sub> -H <sub>24</sub>	-0.026	6.20
						C <sub>19</sub> -N <sub>18</sub> -C <sub>20</sub> -C <sub>21</sub>	-0.0009	0.36
						C <sub>19</sub> -N <sub>18</sub> -C <sub>20</sub> -H <sub>22</sub>	-180.004	179.94
						H <sub>26</sub> -N <sub>18</sub> -C <sub>20</sub> -C <sub>21</sub>	-179.996	-179.90
						H <sub>26</sub> -N <sub>18</sub> -C <sub>20</sub> -H <sub>22</sub>	0.0004	-0.31
						N <sub>17</sub> -C <sub>19</sub> -H <sub>24</sub> ...O <sub>4</sub>	179.993	-168.86
						N <sub>18</sub> -C <sub>19</sub> -H <sub>24</sub> ...O <sub>4</sub>	0.0243	4.37
						N <sub>18</sub> -C <sub>20</sub> -C <sub>21</sub> -N <sub>17</sub>	-0.0012	-0.53
						N <sub>18</sub> -C <sub>20</sub> -C <sub>21</sub> -H <sub>25</sub>	-179.998	-175.38
						H <sub>22</sub> -C <sub>20</sub> -C <sub>21</sub> -N <sub>17</sub>	180.002	179.88
						H <sub>22</sub> -C <sub>20</sub> -C <sub>21</sub> -H <sub>25</sub>	0.006	5.03

is a highly helpful property [42]. Fig. 13, shows that the MEP map of IMGA was obtained by DFT theory B3LYP/6-311++G(d,p) using Gaussian-09. The hydrophobic and hydrophilic components of the IMGA molecules are clearly visible in colour schemes. The hydrophilic sites, with negative carboxylate anions (red colour) and positively charged imidazolium cations (blue colour), may act as proton transport channels. Yellow colour depicts the region that is somewhat electron-rich and light blue depicts the region that

is slightly electron-deficient [43]. The optimum location for an electrophilic attack is shown in the picture where the maximum electron density is localized near the nitrogen atom. The activation energy for imidazolium glutarate is reported to be the lowest (0.7 eV) [11]. The unique stacking of imidazolium rings amongst acid molecules may be the cause of such a low value. This makes it possible to construct a variety of N-H...O contacts, which are essential to the conducting mechanism.

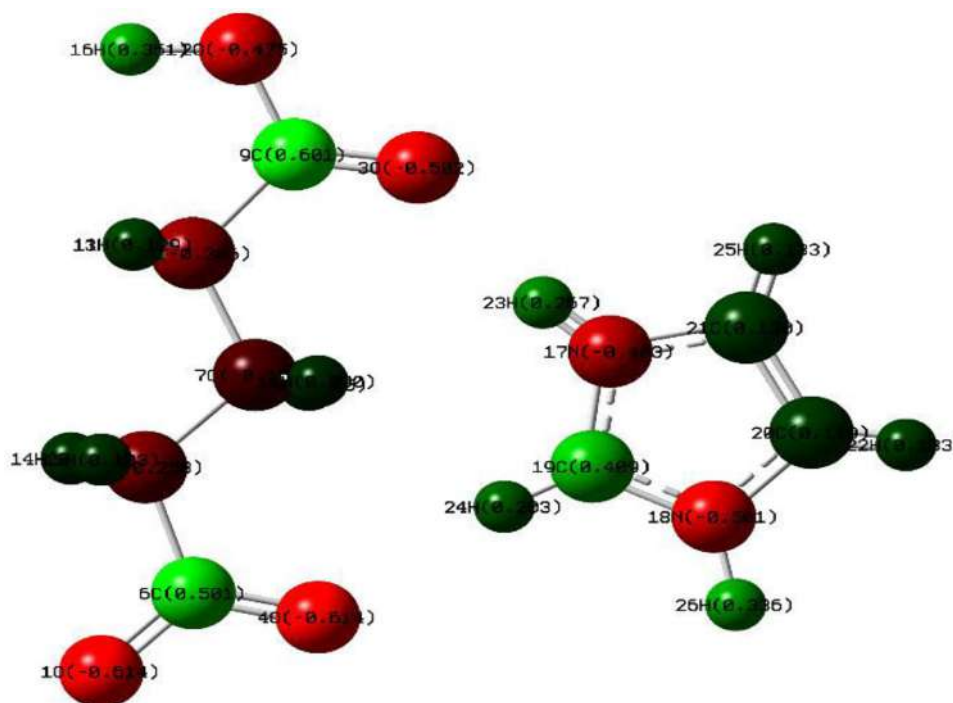


Fig. 12. Mulliken atomic charges of IMGA molecule.

Table 5

HOMO-LUMO and related global chemical reactivity descriptor properties of IMGA molecule.

Molecular properties	Mathematical description	Energy(eV)
$E_{\text{HOMO}}$	Energy of HOMO	-5.5218
$E_{\text{LUMO}}$	Energy of LUMO	-0.4815
Energy Gap	$\Delta E_g = E_{\text{HOMO}} - E_{\text{LUMO}}$	5.0403
Ionization Potential (IP)	$IP = -E_{\text{HOMO}}$	5.5218
Electron Affinity (EA)	$EA = -E_{\text{LUMO}}$	0.4815
Electronegativity ( $\chi$ )	$\chi = -1/2(E_{\text{LUMO}} + E_{\text{HOMO}})$	3.0016
Chemical potential ( $\mu$ )	$\mu = 1/2(E_{\text{LUMO}} + E_{\text{HOMO}})$	-3.0016
Global Hardness ( $\eta$ )	$\eta = 1/2(E_{\text{LUMO}} - E_{\text{HOMO}})$	2.5201
Softness (S)	$S = 1/2\eta$	0.1984
Electrophilicity index ( $\omega$ )	$\omega = \mu^2/2\eta$	1.7875

Table 6

Mulliken atomic charges of IMGA molecule.

Atomic number	Mulliken atomic charge (atomic unit)	Atomic number	Mulliken atomic charge (atomic unit)
10	-0.613678	14H	0.099259
20	-0.475008	15H	0.102988
30	-0.501716	16H	0.351105
40	-1.260807	17N	-0.402936
5C	-0.614360	18N	-0.501291
6C	0.500762	19C	0.409086
7C	-0.162160	20C	0.118553
8C	-0.306131	21C	0.130269
9C	0.600581	22H	0.132886
10H	0.090273	23H	0.266825
11H	0.129468	24H	0.202609
12H	0.095012	25H	0.132585
13H	0.137162	26H	0.335592

### 3.9. NBO analysis

Donor and acceptor orbitals, electron delocalization, intermolecular charge transfer (ICT), and the discovery of hydrogen bonding are all potential interactions that can be discovered via NBO

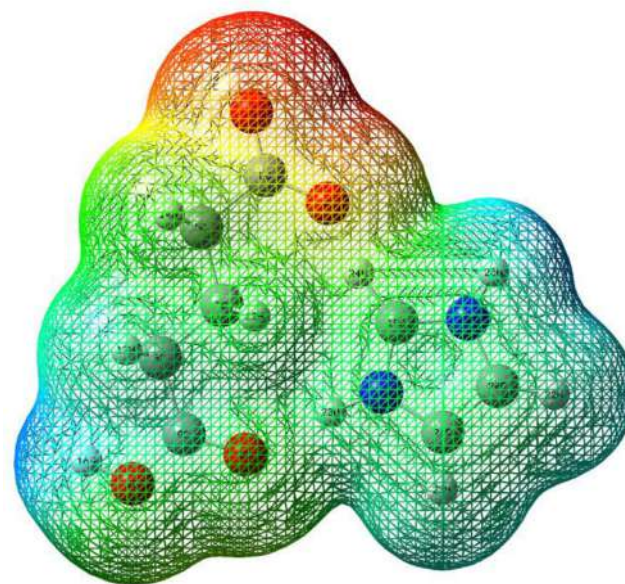


Fig. 13. MEP plot of IMGA molecule.

analysis [44,45]. The NBO computation of the IMGA molecule was evaluated from the NBO 3.1 software program. To determine the stable structure, it is possible to calculate the energy contributions from several orbitals, including LP,  $\pi$ ,  $\pi^*$ ,  $\sigma$ , and  $\sigma^*$ , as a result of electron delocalization and conjugative interactions. It has with the NLO response [46], the system's overall conjugation is stronger and the electrical flow from electron D-A is more intense when the  $E(2)$  value is higher. The various Donor-Acceptor (D-A) interactions present in IMGA are given in Table 7. The maximum stabilization energy ( $E(2)$ ) of 87.88 Kcal/mol corresponds to the delocalization of IMGA with the transfer of LP to  $\pi^*(\text{O}-\text{C})$  within a carboxylate group that is due to strong intermolecular charge transfers

**Table 7**  
Donor-acceptor interactions of IMGA molecule.

Donor (i)	Occupancy (e)	Acceptor (j)	Occupancy (e)	E(2) kcal/mol	E(j)-E(i) (a.u)	F(i,j) (a.u)
$\sigma$ (C5 - C6)	1.98599	$\sigma^*$ (C8 - C9)	0.06308	2.92	0.93	0.047
$\pi$ (O1 - C6)	1.99374	$\pi^*$ (O1 - C6)	0.36456	2.87	0.40	0.034
$\sigma$ (C5 - H15)	1.97310	$\pi^*$ (O1 - C6)	0.36456	3.41	0.64	0.046
$\sigma$ (C7 - C8)	1.97846	$\sigma^*$ (O2 - C9)	0.08346	3.57	0.97	0.053
$\sigma$ (C8 - H11)	1.96882	$\sigma^*$ (O3 - C9)	0.03201	3.73	1.14	0.058
LP(2) O1	1.88271	$\sigma^*$ (O4 - C6)	0.05773	20.31	0.78	0.114
LP(2) O1	1.88271	$\sigma^*$ (C5 - C6)	0.09359	17.73	0.59	0.092
LP(2) O2	1.79589	$\pi^*$ (O3 - C9)	0.23339	52.42	0.36	0.123
LP(2) O3	1.86094	$\sigma^*$ (O2 - C9)	0.08346	29.90	0.68	0.130
LP(2) O3	1.86094	$\sigma^*$ (C8 - C9)	0.06308	14.72	0.68	0.091
LP(2) O4	1.87292	$\sigma^*$ (O1 - C6)	0.06903	20.59	0.78	0.115
LP(2) O4	1.87292	$\sigma^*$ (C5 - C6)	0.09359	16.55	0.63	0.092
LP(3) O4	1.62152	$\pi^*$ (O1 - C6)	0.36456	87.88	0.29	0.143
LP(1) O3	1.97010	$\sigma^*$ (N17 - H23)	0.02719	4.57	1.49	0.074
LP(2) O3	1.97010	$\sigma^*$ (N17 - H23)	0.02719	5.06	1.08	0.068
$\pi$ (N17 - C19)	1.90007	$\pi^*$ (C20 - C21)	0.25088	19.61	0.38	0.080
$\sigma$ (N17 - C21)	1.98491	$\sigma^*$ (C20 - H22)	0.00871	3.11	1.57	0.063
$\pi$ (C20 - C21)	1.85271	$\pi^*$ (N17 - C19)	0.46881	13.23	0.25	0.056
LP(1) N18	1.51994	$\pi^*$ (N17 - C19)	0.46881	79.61	0.25	0.125
LP(1) N18	1.51994	$\pi^*$ (C20 - C21)	0.25088	32.88	0.30	0.094
$\sigma$ (C21 - H25)	1.98452	$\sigma^*$ (N17 - C19)	0.01588	3.21	1.12	0.054
$\sigma$ (C20 - C21)	1.98069	$\sigma^*$ (N17 - H23)	0.02719	3.66	1.58	0.068
$\sigma$ (C20 - C21)	1.98069	$\sigma^*$ (N18 - H26)	0.01350	3.54	1.14	0.057

LP(3) O4  $\rightarrow$   $\pi^*$ (O1-C6)). The delocalization of IMGA with the transfer of LP(1) N18  $\rightarrow$   $\pi^*$ (N17-C19) and LP(2) O2  $\rightarrow$   $\pi^*$ (O3-C9) possesses the E(2) of 79.61 and 52.42 Kcal/mol, respectively and showing that the formed crystal has a conjugative impact. The other strong delocalization of 32.88 and 29.90 Kcal/mol is produced by the conjugation with the lone pair of LP(1) N18 and LP(2) O3 when it is combined with  $\pi^*$ (C20 - C21) and O2 - C9), respectively. In IMGA, the D-A interactions are formed  $\sigma^*$ (by the orbital overlaps through  $\pi \rightarrow \pi^*$  and  $\sigma \rightarrow \sigma^*$  interactions such as  $\pi$ (C20 - C21)  $\rightarrow$   $\pi^*$ (N17 - C19) and  $\sigma$ (C20 - C21)  $\rightarrow$   $\sigma^*$ (N17 - H23) with the E(2) of 13.23 and 3.66 Kcal/mol, respectively. Herewith the important D-A interactions are discussed and the other D-A interactions are given in Table 7.

From the Table 7.

E(2) means stabilization energy.

E(j)-E(i) is the energy difference between donor and acceptor i and j NBO orbitals.

F(i,j) is the Fock matrix element between i and j NBO orbitals.

### 3.10. Hyperpolarizability studies

The relationship between the molecular structure and NLO properties can be understood by using theoretical determinations of hyperpolarizability [47,48]. The dipole moment ( $\mu$ ), mean polarizability ( $\alpha$ ), and first-order hyperpolarizability ( $\beta$ ) for IMGA in terms of x, y, and z components have been calculated using the density functional theory (B3LYP/6-311++G(d,p)). The formulas for computing  $\mu$ ,  $\alpha$ ,  $\beta$  are given by the following reference [24]. The calculated values of IMGA are given in Table 8. It shows the total molecule dipole moment and first-order hyperpolarizability, which are 10.3163 Debye and  $0.96 \times 10^{-30}$  esu, respectively. The dipole moment of the IMGA molecule is 7 times larger than urea, and its first-order hyperpolarizability is 2.5 times larger than urea's (the dipole moments of urea are 1.3732 Debye and  $0.3728 \times 10^{-30}$  esu, respectively, as determined using the B3LYP/6-311++G(d,p) method). The intramolecular charge transfer caused by the migration of the electron cloud from an electron donor to acceptor groups through the conjugate framework is linked to the large value of hyperpolarizability [49,50], which is a measure of the NLO features of the molecular system.

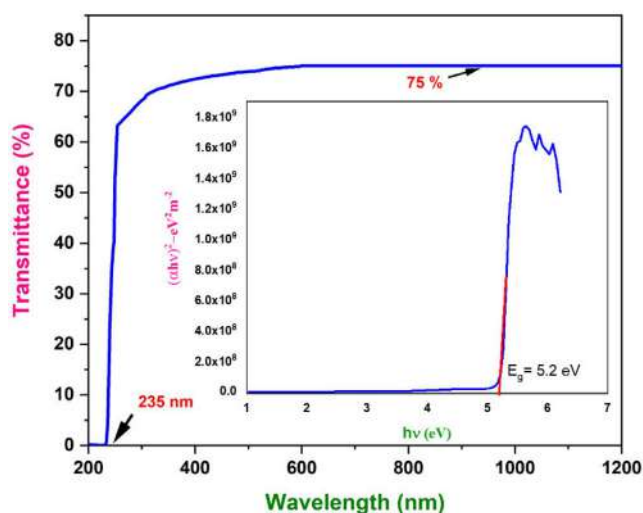


Fig. 14. UV-Vis-NIR transmission spectrum and Tauc plot of IMGA crystal.

### 3.11. UV-Vis-NIR studies

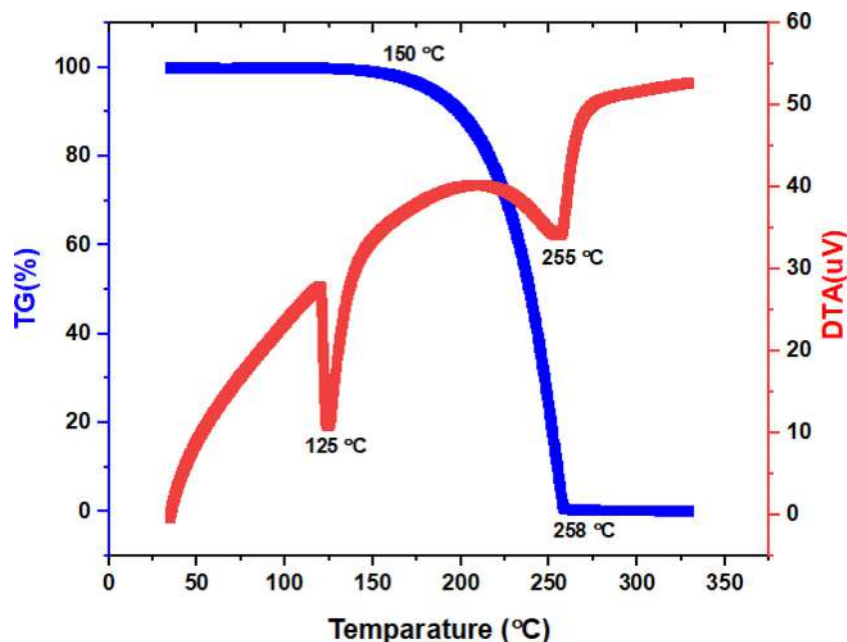
The optical transmittance range and cut-off wavelength are essential factors to customize the material for particular device applications. The majority of uses for single crystals are in optical technology. Using a UV-Vis-NIR spectrophotometer, the UV-Vis-NIR spectrum of IMGA was recorded from 200 to 1200 nm. For the optical transmittance studies, a high-quality, (101) plane cut-and-polished 1 mm thickness wafer was used. Fig. 14 displays the transmittance spectrum of IMGA crystal. It shows that grown crystal has ~75% transmittance from 350 to 1200 nm and this value is enough for blue-light applications and SHG Laser radiation at 1064 nm [51]. The lower cut-off wavelength of the grown crystal is 235 nm. The optical band gap  $E_g$  was calculated from Tauc's expression is

$$(\alpha h\nu)^2 = A(h\nu - E_g)$$

where  $\alpha$  is the absorption coefficient,  $n = 2$  for direct transition, A is a constant and h is a Plank constant. Fig. 14 the linear part of

**Table 8**  
NLO properties of IMG A molecule.

Dipole moment		Polarizability		First order hyperpolarizability	
$\mu_x$	3.0126	$\alpha_{xx}$	-36.6050	$\beta_{xxx}$	38.4855
$\mu_y$	-9.8666	$\alpha_{yy}$	-122.9427	$\beta_{yyy}$	-156.9134
$\mu_z$	0.0017	$\alpha_{zz}$	-81.0054	$\beta_{zzz}$	-0.0024
$\mu_{total}$	10.3163	$\alpha_{xy}$	3.9975	$\beta_{xyy}$	43.3169
		$\alpha_{yz}$	-0.0029	$\beta_{xxy}$	-36.6993
		$\alpha_{zx}$	0.0018	$\beta_{xxz}$	0.0084
		$\alpha_{total}$	$-1.19 \times 10^{-23}$ esu	$\beta_{xzz}$	-11.3439
		$\Delta_\alpha$	$1.45 \times 10^{-23}$ esu	$\beta_{yzz}$	1.2393
				$\beta_{yyz}$	0.0157
				$\beta_{xyz}$	0.0005
				$\beta_{total}$	$0.96 \times 10^{-30}$ esu



**Fig. 15.** TG-DTA curve of IMG A crystal.

the curve plotted by  $(\alpha h\nu)^2$  vs photon energy ( $h\nu$ ) and gives the direct optical band gap energy ( $E_g$ ) [13]. The estimated  $E_g$  value of IMG A crystal is 5.2 eV.

### 3.12. TG-DTA studies

Simultaneous TG-DTA was performed on the grown IMG A crystals using a PerkinElmer Diamond TG-DTA analyser and a nitrogen environment, the temperature range used was between 30 °C and 400 °C with a 10 °C/min heating rate. Fig. 15 shows the TG/DTA curves of the IMG A crystal. The IMG A crystal is stable up to 150 °C, according to the TG curve, and material weight loss occurs between 150 and 258 °C. The DTA curve clearly displays two endothermic peaks, with the first peak around 125 °C signifying the melting point of the title crystal and the second peak at 255 °C signifying the material's decomposition point. The grown crystal begins to disintegrate after 99% of its weight is eliminated as gaseous products, with the remaining 1% being made up of leftover carbons. The TG-DTA studies confirm that melt growth is also possible to grow the IMG A crystal.

### 3.13. Dielectric studies

The electrical response of the crystal, which is a key factor in the design of optoelectronic devices [52], can be examined using the dielectric properties of the materials. To measure dielec-

tric properties of IMG A single crystal (2 0 2) plane parallel plates at room temperature using Agilent 4284A Precision LCR METRE in the frequency region 50 Hz - 1 MHz. For a good electrical connection, a silver paste was electrode on the surface of the relevant crystal sample. The dielectric constant and loss of the sample were calculated by the following reference [53]. Fig. 16 depicts how the dielectric constant and dielectric loss (Inset Fig. 16) varies with frequency. From 50 Hz to 10,000 Hz, the dielectric constant and loss is greater and rapidly decrease with increasing frequency, continuing up to 1 MHz. After this, it almost remains the same at higher frequencies. The crystal's good optical quality and lack of defects, which is a desirable property for NLO applications [53], is revealed by the low value of dielectric loss and good dielectric constant at high frequencies.

### 3.14. Z-Scan studies

One of the simplest techniques created by Eric Stryland to measure NLO constants, such as non-linear absorption (NLA) and refraction (NLR), is Z-scan [54]. This method was created for potential uses such as multi-photon polymerization and optical limiting and switching [55,56]. It can simultaneously measure the magnitude and sign of the NLR ( $n_2$ ) and the NLA ( $\beta$ ) of the samples. The input parameters for the Z-scan experiment are given in Table 9. The (101) plane cut and polished 1 mm thickness sample was used for the Z-scan experiment. The Z-scan data for the closed aperture



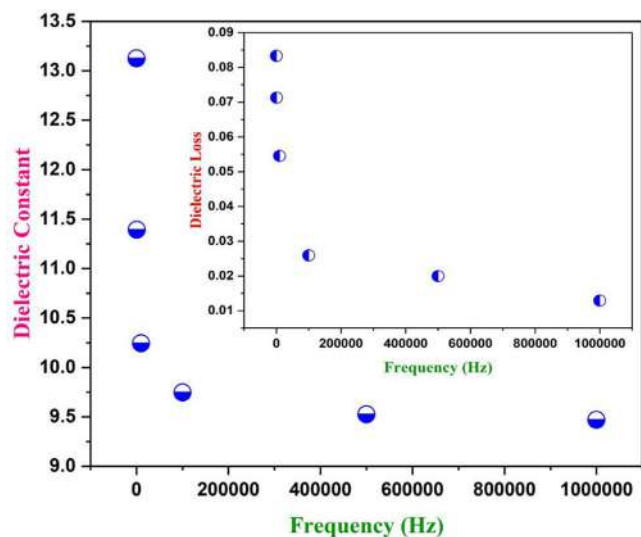


Fig. 16. Dielectric constant and dielectric loss of IMGA crystal at different frequency.

**Table 9**  
Z-scan measurement parameters.

Test Parameters	
Sample thickness (L)	1 mm
Rayleigh length	1.29 mm
Laser beam wavelength ( $\lambda$ )	632.8 nm
Beam radius at the aperture ( $w_a$ )	9 mm
Aperture radius ( $r_a$ )	2 mm
Laser beam intensity ( $I_0$ )	15.31 MW/m <sup>2</sup>

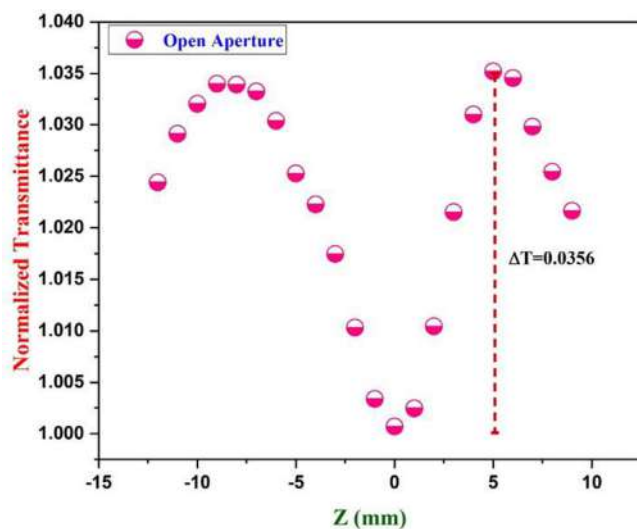


Fig. 17. Open aperture spectrum of IMGA single crystal.

configured for IMGA at the transmission of around 75% is shown in Fig. 17. The valley is followed by a peak-normalized transmittance which is the characteristic of positive nonlinearity. The calculated  $\Delta T_{P-V}$  value is 1.1895. The NLA coefficient ( $\beta$ ) is examined and calculated using the open aperture Z-scan spectrum. The open aperture spectrum of the IMGA sample is shown in Fig. 18. It demonstrates that the intensity of transmitted light decreases as the sample gets closer to the focus point, providing conclusive

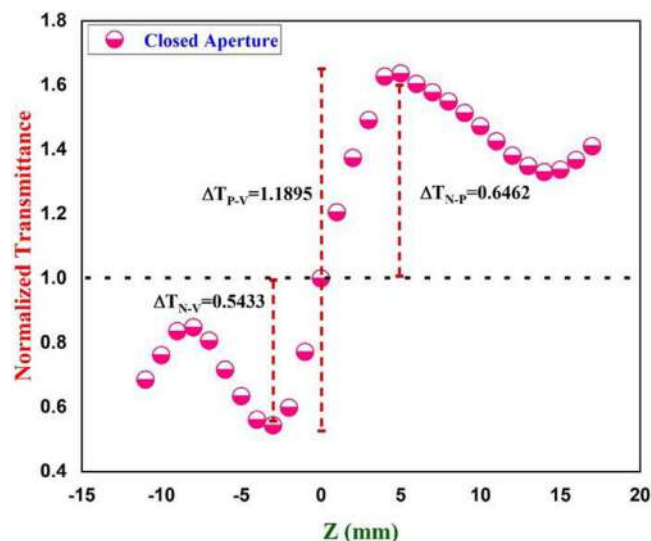


Fig. 18. Closed aperture spectrum of IMGA single crystal.

**Table 10**  
Parameters measured in Z - scan experiment.

Parameters	Calculated values
$\Delta T_{P-V}$	1.1895
$\Delta T$	0.0356
Linear refractive index at 632.8 nm	1.548
Linear absorption co-efficient ( $\alpha$ )	3.07 cm <sup>-1</sup>
Nonlinear refractive index ( $n_2$ )	$2.30 \times 10^{-12}$ m <sup>2</sup> /W
Nonlinear absorption co-efficient ( $\beta$ )	$7.64 \times 10^{-6}$ m/W
Real part of the third-order susceptibility [ $Re \chi^{(3)}$ ]	$1.395 \times 10^{-10}$ esu
Imaginary part of the third-order susceptibility [ $Im \chi^{(3)}$ ]	$2.274 \times 10^{-7}$ esu
Third-order nonlinear optical susceptibility ( $\chi^{(3)}$ )	$2.274 \times 10^{-7}$ esu

proof of the reverse saturable absorption (RSA) phenomenon. The calculated  $\Delta T_{P-V}$  value is 0.0356. Both the NLA coefficient and NLR contribute to the third-order NLO property of the crystal. The formulas for finding third-order NLO and related parameters are given detailed in Ref. [4] and calculated parameters in Z - the scanning experiment are given in Table 10. The relatively high value of third-order NLO susceptibility ( $\chi^{(3)}$ ) suggests that grown crystal is suitable for optical limiting-related applications.

#### 4. Conclusion

IMGA crystal has been synthesized and its crystal structure has been confirmed from SCXRD and PXRD studies. The optimized geometric parameters have been theoretically calculated and compared with the experimental data. The presence of proton and carbon was confirmed by <sup>1</sup>H and <sup>13</sup>CNMR spectra. The bandgap energy of the material is 5.2 eV. The dominant IMIs of the total HS for IMGA molecule are H...H (36.6%) interactions and the proportions of O...H and H...O interactions comprise 52.1% of the total Hirshfeld surface for each molecule. The calculated GCRD such as electronegativity ( $\chi$ ) and electrophilicity index ( $\omega$ ) values are 3.0016 and 1.7875 eV, respectively. The delocalization of IMGA with the transfer of LP(1) N18  $\rightarrow$   $\pi^*(N17-C19)$  and LP(2) O2  $\rightarrow$   $\pi^*(O3-C9)$  possesses the E(2) of 79.61 and 52.42 Kcal/mol, respectively. The dipole moment of the IMGA molecule is 2.5 times larger than urea, and its first-order hyperpolarizability is 7 times larger than urea. The values of nonlinear RI ( $n_2 = 2.30 \times 10^{-12}$  m<sup>2</sup>/W) and 3rd order nonlinear susceptibility ( $\chi^3 = 2.274 \times 10^{-7}$  esu) were estimated using Z-scan studies. The

wide bandgap, high dielectric constant, and  $\chi^3$  values suggest that the grown crystal is suitable for optoelectronic applications.

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The authors declared no potential conflicts of interest.

### CRediT authorship contribution statement

**Gino DJ:** Formal analysis, Investigation, Data curation, Writing – original draft. **Chinnasami Sidden:** Investigation, Validation, Writing – review & editing. **Rajesh Paulraj:** Conceptualization, Project administration. **H. Marshan Robert:** Validation, Investigation. **S. Ajitha:** Funding acquisition, Supervision, Project administration.

### Data availability

Data will be made available on request.

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## Studies on the Investigation of Anti-Oxidant and Cellular Toxicity on L929 Cell Line of *Andrographis paniculata* and its Derivative of Silver and Gold Nanoparticles

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**ABSTRACT:** The current pharmaceutical industry is increasingly turning to plant-based multi-potential bioactive compounds to combat a variety of diseases and pathological conditions due to the consequences of administrating synthetic drugs. To Avoid back reflection of synthetic drugs, researchers are focusing on natural derivatives guided from traditional medical practices. Plants are playing vital role in nutritional and disease control aspects in traditional era. Terrestrial resources contain a vast array of medicinally valuable plants that have traditionally been used to treat a wide range of diseases, including hepatoprotective, anti-inflammatory, antibacterial, anti-cancer, and antidiabetic properties. Similarly, the study plant *Andrographis paniculata* demonstrated significant medicinal properties; thus, the potential activity of a leaf ethanolic extract of *A. paniculata*, diethyl phthalate purified from the crude ethanolic extract, and their modified metal (Silver and Gold) nanoparticles against free radicals, namely DPPH and phosphomolebdenum assays. In addition, the study samples were subjected to an MTT assay to assess cellular toxicity in comparison to the L929 cell line. The results showed that the promising drug carrier system of diethyl phthalate silver nanoparticles (DPAgNPs) exhibited lower toxicity and higher anti-oxidant activity.

**Keywords:** *Andrographis paniculata*, Diethyl phthalate, Silver and gold nanoparticles, DPPH, Phosphomolebdenum and Cytotoxicity.

### INTRODUCTION

Countless plant-based products, such as herbal teas, nutritional supplements, health meals, and other goods, are readily available today (Phillips and Meilleur 1998). Distinct medical traditions are practised by various cultural and ethnic groups (Leslie and Young 1992). In underdeveloped nations, where 65 to 80 percent of the world's population resides, plant products are their primary source of healthcare (Farnsworth *et al.*, 1985; Awoyemi *et al.*, 2012). Ayurveda has been demonstrated to be one of the oldest medical systems that is still in use today, both in India and around the world. Many individuals think natural treatments are safer than synthetic medications. Individualized therapies may incorporate nutritional, physical activity, and lifestyle factors as well as proprietary molecules or plant components (Sharma and Mujundar 2003). There has been a remarkable return of interest in medicine and classical pharmacopoeia despite substantial advancements in contemporary medicine. Perumal and Gopalakrishnakone (2008) explored plant-based medications, which significantly improved on already available therapies. Plants continue to play a key role in

the control of diabetes, particularly in much less developed countries where the bulk of the population has little resources and no access to contemporary therapy. Alternative diabetes therapies, such as those based on plants, are becoming more and more popular in industrialised nations due to the drawbacks of taking insulin and oral hypoglycemic medications (Marles and Farnsworth 1994). In India, where more than 30 million individuals have the condition, diabetes is on the increase. Numerous members of society are impacted by undiagnosed diabetes. Both diabetes screening and the streamlining of diagnostic processes have become crucial. The two most prevalent kinds of diabetes are Type-1 and Type-2 (Gupta *et al.*, 2014; Wang *et al.*, 2001). Phenolic compounds are a significant category of the plant secondary metabolites that have been found to have antioxidant properties. There are several findings on how phenolic chemicals affect the antioxidant capacity of various plant species (Cai *et al.*, 2004). Diverse pharmacological effects of *Andrographis paniculata* exist, some of which include anti-cancer, anti-diarrheal, and anti-hepatitis (Md. Sanower Hossain *et al.* (2014). *A. paniculata* extracts show hepatoprotective qualities, antihypertensive

effects, and lower plasma angiotensin converting enzyme (ACE) activity and renal lipid peroxidation (Akbar, 2011). Besides, they have antimicrobial, anti-inflammatory, antioxidant, and hypoglycemic effects (Zhang and Tan 2000). In an effort to discover a treatment for conditions like rheumatoid arthritis and ulcerative colitis that are brought on by oxidative stress and infections, Umadevi and Kamalam (2014) at the University of Bristol investigated *A. paniculata*. They are looking at the phytochemical composition and antioxidant capacities of the plant. Similar to this, 10% methanolic SLE showed enhanced antioxidant activity, which was responsible for 53.94 g/ml DPPH activity and 44.94% suppression of nitric oxide activity (Uthirapandi *et al.*, (2021). Penicillin has a wide range of possible uses, including as an anti-microbial, cytotoxic, anti-protozoan, and immunostimulant, according to a review by Okhuarobo *et al.* (2014). Andrographolide, the primary active ingredient, has a variety of biological effects, including hepatoprotective, anti-inflammatory, antibacterial, anti-cancer, and antidiabetic ones (Jarukamjorn and Nemoto 2008). Researchers suggest that andrographolide be structurally modified in order to acquire diverse leads due to the outstanding diversity of these biological functions. Numerous andrographolide compounds have surfaced in recent decades, and their pharmacological properties have also been examined. There haven't been many researches that thoroughly summaries or analyze *A. paniculata* and its derivatives, nevertheless. As a result, this study gives comprehensive information about the pharmacological activity of *A. paniculata* and its main ingredient andrographolide in an effort to advance the trends of research on andrographolide (Jayakumar *et al.*, 2013). Antioxidant defences are strengthened by andrographolide. By scavenging free radicals, it exerts direct action. It further causes indirect interference by preserving mitochondrial integrity, preventing pro-oxidant enzyme activity, and/or activating antioxidant enzymes. Keep in mind that the control of the antioxidant defense system involves the transcription factor Nrf2. As a result, andrographolide's regulation of Nrf2 is important for controlling the redox system (Li *et al.*, 2018; Tan *et al.*, 2018; Yan *et al.*, 2018).

## MATERIAL AND METHODS

**Sample Preparation.** Around 50 g of powdered *Andrographis paniculata* was taken into fresh extract cloth and bagged into extraction apparatus. The system was placed on the heating mantle at 40°C and the sample with reflux condenser tube was placed over the solvent collector with air tightly. The extraction system was started with 500 ml ethanol as extraction solvent for 24 hours. After extraction the solvent was transferred to fresh 500 ml conical flask, filter the extract and stored at 4 °C for further analysis. Diethyl phthalate was partially purified from the crude extract of *A. paniculata* using column chromatography and has been characterised spectrally. From the diethyl phthalate chromatographic fraction, silver and gold nanoparticles were synthesised using ascorbic acid as a

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reducing agent and subjected to spectral and morphological characterization.

### Anti-Oxidant Property

**DPPH radical scavenging activity.** The free radical scavenging activity of the fractions was measured in vitro by the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay according to the standard method (Brand-Williams *et al.*, 1995). The stock solution was prepared by dissolving 24 mg of DPPH in 100 ml of methanol stored at 4–20 °C. About 4 ml of various concentrations of samples (20, 40, 60, 80, and 100 g/mL) were mixed with 1 ml of methanolic solution containing DPPH radicals, resulting in a final concentration of DPPH of 0.2 mM. The mixture was shaken vigorously and left to stand for 30 minutes, and the absorbance was measured at 517 nm. Ascorbic acid was used as a control. The percentage of DPPH decolorization in the sample was calculated according to the equation. The control was prepared without any sample, and scavenging activity was estimated based on the percentage of DPPH radicals scavenged using the following equation:

$$\% \text{ of inhibition} = [(control \text{ OD} - sample \text{ OD}) / (control \text{ OD})] \times 100$$

**Total antioxidant activity.** Each test tube contained 3 mL of distilled water and 1 mL of Molybdate reagent solution, as well as 20-100 µg/mL of *Andrographis paniculata* extract, Diethyl phthalate (DP), DP silver nanoparticles (DPAgNPs), and DP gold nanoparticles (DPAuNPs). These tubes were kept incubating at 95 °C for 90 min. After incubation, these tubes were normalized to room temperature for 20–30 min, and the absorbance of the reaction mixture was measured at 695 nm. The percentage of inhibition values from samples was calculated for each extract. Ascorbic acid was used as a positive reference standard. The PM assay is based on the reduction of phosphate-Mo (VI) to phosphate-Mo (V) by the sample and the subsequent formation of a bluish-green phosphate/Mo (V) complex at an acidic pH. The phosphomolybdenum method is routinely applied in the laboratory to evaluate the total antioxidant capacity of plant extracts (Prieto *et al.*, 1999).

**Cellular Cytotoxicity on L929 Cell line by MTT assay.** This assay was performed based on the assessment of reduction of the yellow colored water soluble tetrazolium dye MTT to formazan crystals (MTT Cell Proliferation Assay Instruction Guide). Mitochondrial lactate dehydrogenase produced by live cells reduces MTT to insoluble formazan crystals formed in assay mixture. Seed 200µl cell suspension in a 96-well plate at required cell density (20,000 cells per well), without the test agent. Allow the cells to grow for about 24 hours. Add appropriate concentrations of the test samples (Diethyl phthalate, DPAgNPs and DPAuNPs) incubate the plate for 24hrs at 37°C in a 5% CO<sub>2</sub> atmosphere. After the incubation period, takeout the plates from incubator and remove spent media and add MTT reagent to a final concentration of 0.5mg/mL of total volume. Wrap the plate with aluminium foil to avoid exposure to light. Return the plates to the incubator and incubate for 3 hours. (Note: Incubation time varies for different cell lines. Within one

experiment, incubation time should be kept constant while making comparisons). Remove the MTT reagent and then add 100µl of solubilisation solution (DMSO). Gentle stirring in a gyratory shaker will enhance dissolution. Occasionally, pipetting up and down may be required to completely dissolve the MTT formazan crystals especially in dense cultures. Read the absorbance on a spectrophotometer or an ELISA reader at 570 nm wavelength. % Cell viability is calculated using below formula:

% cell viability=[Mean abs of treated cells/Mean abs of Untreated cells] × 100

**Statistical Analysis.** The obtained data were interpreted and calculated as Mean, Standard deviation and ANOVA using IBM SPSS Statistical Software and represented the data in tables as well as graphs.

## RESULT AND DISCUSSION

### Phytochemical Screening

#### Anti-Oxidant Activity

**DPPH Scavenging Assay.** The study samples (*A. paniculata*, Diethyl phthalate, DPAGNPs and DPAGNps) were subjected to investigate the scavenging activity against 2-diphenyl-1-picrylhydrazyl (DPPH) and the scavenging effects were analyzed and calculated statistically. Among the sample Diethyl phthalate silver nanoparticles (DPAGNPs) were described in Table and Figure: 1 as higher scavenging activity 60.36 % at 100 µg/mL concentration while *A.paniculata* showed 44.94 % at 100 µg/mL. However, Diethyl phthalate and DP gold nanoparticles exhibited quite lower scavenging effect as 16.42 % and 20.83 % at 100 µg/mL concentration. The one-tailed ANOVA was performed and showed insignificance of activity among the sample at p-value equals 1.738 (1.738 > p 0.005) greater than  $\alpha$  value of 0.005 (Table and Fig. 2).

**Total Anti-oxidant Activity.** Total anti-oxidant property can be determined by analyzing the reducing activity of phosphate-Mo (VI) to phosphate Mo (V) was measured at 695 nm. In table and Figure: 3 Higher reducing property was shown in Diethyl phthalate silver nanoparticle (DPAGNPs) as 83.64 % at the concentration of 100 µg/mL while, DP gold nanoparticle exhibited lesser activity 14.29 % at 100 µg/mL. In other hand, Diethyl phthalate revealed 57.56 % and *A.paniculata* has 34.78 % of reducing activity at 100 µg/mL. The data of total anti-oxidant property was far away to significant at 0.005 level (1.088 > p 0.005) showed in Table and Fig. 4.

#### Assessment of Cellular Cytotoxicity by MTT Assay.

MTT assay is a colorimetric assessment based on the reduction of the yellow colored water soluble tetrazolium dye MTT to formazan crystals by mitochondrial lactate dehydrogenase produced by live cells which in turn represented the percentage of cellular cytotoxicity of L929 cell line. Among the sample group, DP gold nanoparticle showed 87.9 % cytotoxicity to the cell line at the concentration of 100 µg/mL. While, diethyl phthalate and DPAGNPs exhibited 90.13 and 89.68 % of toxicity at 100 µg/mL in Table 5 and Fig. 7 and 8. This revealed the content of concentration depending cellular toxicity against L929

cell line. The toxicity of study samples were analyzed through one-tailed ANOVA and the value showed the significance at p 0.005 and there is no significant difference between the means of any pair (Table 6 and Fig. 5 and 6).

## DISCUSSION

The activities of catalase, superoxide dismutase, and glutathione S transferase are significantly increased when the aqueous extract of *A. paniculata* is administered orally at a variety of dosages. It highlights the antioxidant properties of the aqueous extract of AP, which may contribute to the anticarcinogenic effect by lowering oxidative stress (Verma and Vinayak 2008). According to a study, the antioxidant activity of an *Andrographis paniculata* aqueous extract was higher than that of an ethanol extract. The aqueous extract has a radical scavenging activity of 66.8% at 50 µg/mL compared to 57.8% in the ethanol extract (Mussard *et al.*, 2019). Methanolic plant extracts were most effective in scavenging DPPH free radicals and H<sub>2</sub>O<sub>2</sub> radicals, with 50% inhibition at concentrations of 333.34 µg/ml and 398.12 µg/ml, respectively (Sinha and Raghuwanshi 2020). The aqueous stem extract (4.42 µg/mL) and ethanolic stem extract (6.84 µg/mL) had the lowest IC<sub>50</sub> values, respectively. As a result, the aqueous extract of stem is the most effective in neutralising free radicals produced by the oxidation of lipids, proteins, and nucleic acids (Polash *et al.*, 2017). The results of the present research conducted by Khan *et al.* (2020) showed that andrographolide decreased DLD1 cells ability to divide in a concentration- and time-dependent way. Through nuclear condensation, phosphatidylserine externalisation, and caspase-3 activation, andrographolide triggered apoptosis. Additionally, it increased the levels of cellular ROS, which were linked to the activation of apoptosis in DLD1 cells. Additionally, andrographolide showed synergistic efficacy against DLD1 cells when combined with 5-FU and PTX. According to methodology, plant component, and type of dietary supplement, antioxidant activity ranged from 503.36 to 6164.09 µmol TE/100 g d.m. when tested using the FRAP, CUPRAC, and DPPH procedures (Marzanna Kurzawa *et al.*, 2015). According to research on the anti-oxidant properties of *A. paniculata* ethanolic leaf extract, diethyl phthalate, DPAGNPs, and DPAGNPs against DPPH radicals and phosphomolebdenum, DPAGNPs has shown remarkable anti-oxidant activity at 100 µg/mL concentration, and the IC<sub>50</sub> value was 8.93 µg/mL for DPPH scavenging and 35.13 µg/mL for reducing phosphomolebdenum. Diethyl phthalate is an oily, colourless liquid with no odour or flavour. It can be found in toothbrushes, car components, toys, tools, cosmetics, aspirin, plastics, pesticides, and food packaging (World Health Organization, 2003). These findings imply that DEP exposure may cause sperm effects, hepatic effects, developmental effects, and androgen-independent male reproductive toxicity, with some indications of female reproductive toxicity. To thoroughly analyse these results and boost trust in this database, more study is required (Weaver *et al.*, 2020). The growth of human

HaCaT keratinocytes in cell culture was significantly inhibited by andrographolide at 31.25  $\mu\text{g/mL}$  (90 M). To the best of our knowledge, this is the first time andrographolide from *A. paniculata* has been documented to have anti-proliferative effects. According to OECD test guideline No. 420, *A. paniculata* was evaluated. The standardised FTLEE of *A. paniculata* was given orally to mice in four groups, two of each sex (0, 300, 2000, or 5000 mg/kg BW). Body weight, poisoning symptoms, and/or death were tracked for 14 days after therapy. Animals were put to death at day 15, their internal organs were severely examined, and blood samples were taken for haematological and clinical biochemistry tests. The findings demonstrated that all of the treated animals lived, and no obvious side effects were noticed over the course of the trial. Extensive necropsy examination of

all the standardised FTLEE-treated animals showed no lesions in any organs. Despite the fact that substantial changes in BUN, lymphocytes, neutrophils, hematocrit, and haemoglobin were seen, these changes were not harmful side effects of the therapy. Therefore, we came to the conclusion that there are no significant acute toxicological effects from a single oral administration of the standardised FTLEE of *A. paniculata* with an upper fixed dosage of 5000 mg/kg BW (Worasuttayangkum *et al.*, 2019). Assessment of cellular toxicity of study samples such as *A. paniculata*, diethyl phthalate, DPAGNPs, and DPANPs showed minimal toxicity, while a DP gold nanoparticle showed 87.9% cytotoxicity to the cell line at a concentration of 100  $\mu\text{g/mL}$ . While diethyl phthalate and DPAGNPs exhibited 90.13 and 89.68% of their toxicity at 100  $\mu\text{g/mL}$  in L929 (mouse fibroblast cell line).

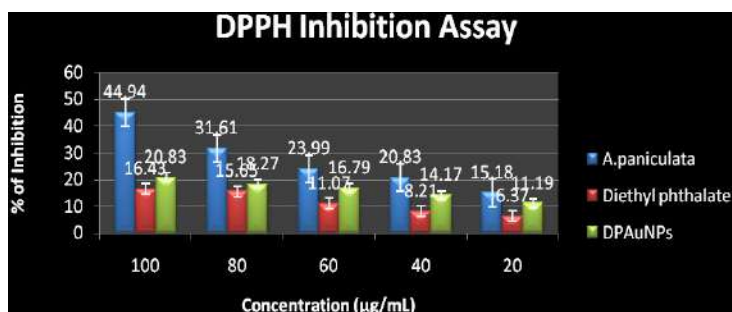


Fig. 1. Inhibitory percentage of study samples against DPPH radicals.

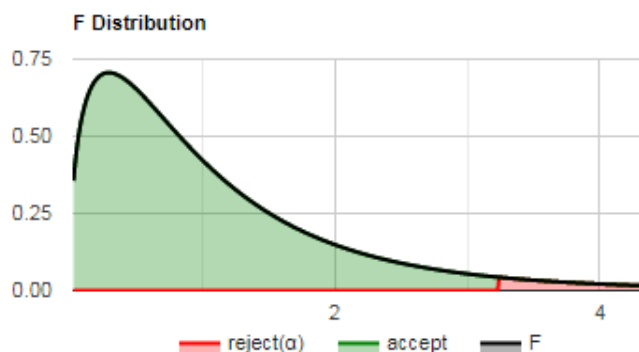


Fig. 2. One-tailed ANOVA of F-distribution of Sample groups

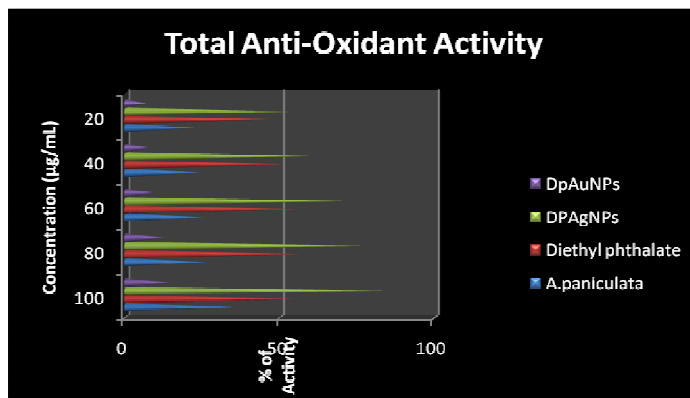
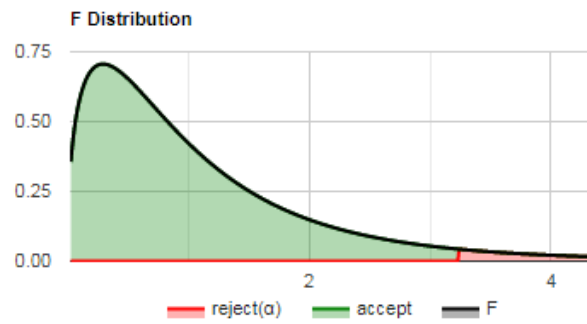
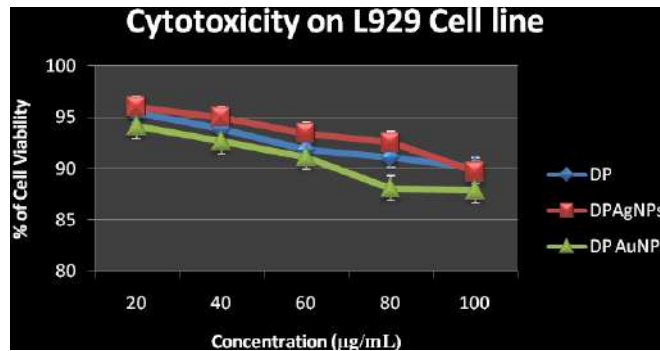


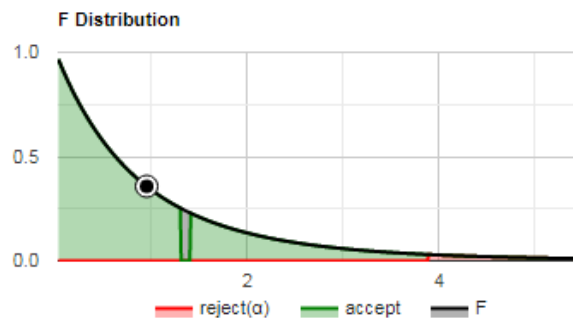
Fig. 3. Total Anti-oxidant activity by Reduction of Phosphomolebdenum



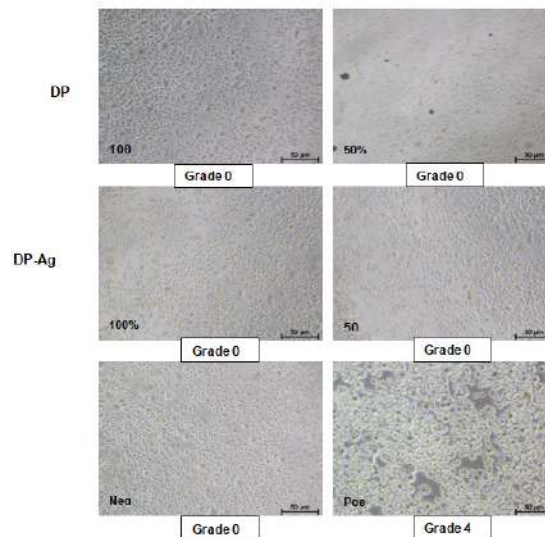
**Fig. 4.** One-tailed ANOVA of F-distribution of Sample groups.



**Fig. 5.** Cellular toxicity effect of study samples on L929 cell line by MTT assay.

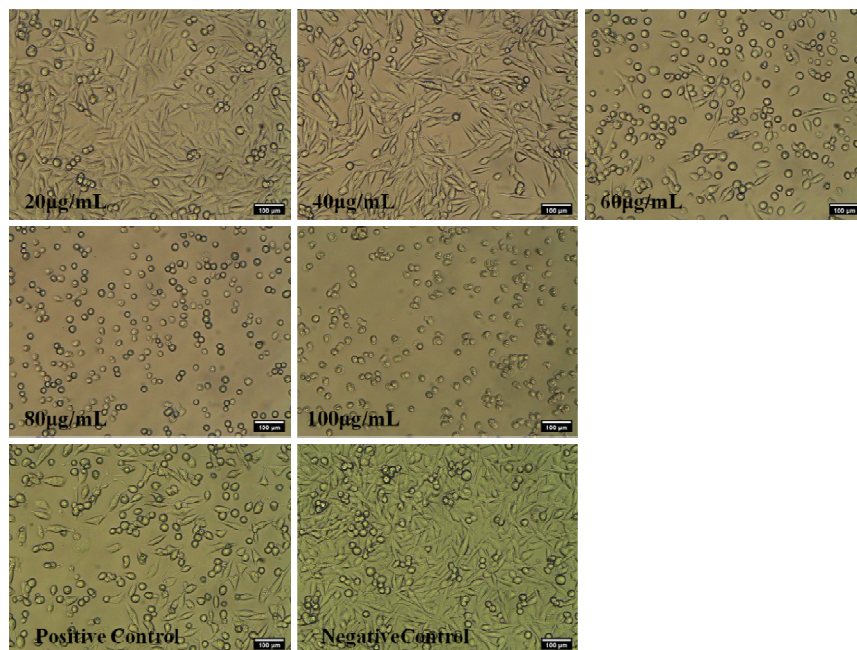


**Fig. 6.** One-tailed ANOVA of F-distribution of Sample groups for Cytotoxicity effects on L929 cell line.



**Fig. 7.** Microscopic examination of cellular Anti-proliferation (Cytotoxicity) on L929 cell line of Diethyl phthalate and Diethyl phthalate Silver nanoparticles.





**Fig. 8.** Microscopic examination of cellular Anti-proliferation (Cytotoxicity) on L929 cell line of Diethyl phthalate Gold nanoparticles

**Table 1: Inhibitory percentage of study samples against DPPH radicals.**

Concentration (µg/mL)	<i>A. paniculata</i>	Diethyl phthalate	DPAgNPs	DPAuNPs
100	44.94 ± 0.001	16.43 ± 0.001	60.36 ± 0.003	20.83 ± 0.001
80	31.61 ± 0.002	15.65 ± 0.001	56.9 ± 0.001	18.27 ± 0.001
60	23.99 ± 0.004	11.07 ± 0.001	53.51 ± 0.001	16.79 ± 0.001
40	20.83 ± 0.001	8.21 ± 0.002	51.13 ± 0.001	14.17 ± 0.001
20	15.18 ± 0.004	6.37 ± 0.001	47.62 ± 0.001	11.19 ± 0.001
<b>IC 50</b>	124.73	341.04	35.13	351.41

**Table 2: One-tailed ANOVA of Sample groups for DPPH scavenging activity.**

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
<b>Groups</b> (between groups)	3	5390.2231	1796.741	37.7456	1.738e-7
<b>Error</b> (within groups)	16	761.6213	47.6013		
<b>Total</b>	19	6151.8444	323.7813		

**Table 3: Total Anti-oxidant activity by Reduction of Phosphomolebdenum.**

Concentration (µg/mL)	<i>A.paniculata</i>	Diethyl phthalate	DPAgNPs	DpAuNPs
100	34.78 ± 0.01	57.56 ± 0.011	83.64 ± 0.040	14.29 ± 0.1
80	26.17 ± 0.001	56.85 ± 0.002	76.6 ± 0.015	12.42 ± 0.1
60	25.49 ± 0.001	55.57 ± 0.003	71.01 ± 0.015	10.56 ± 0.1
40	24.55 ± 0.003	51.86 ± 0.003	60.04 ± 0.015	8.7 ± 0.1
20	22.75 ± 0.003	49.88 ± 0.002	54.45 ± 0.015	6.83 ± 0.1
<b>IC 50</b>	539.38	17.52	8.93	591.01

**Table 4: One-tailed ANOVA of Sample groups for Total anti-oxidant activity.**

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
<b>Groups</b> (between groups)	3	10488.5862	3496.1954	76.176	1.089e-9
<b>Error</b> (within groups)	16	734.341	45.8963		
<b>Total</b>	19	11222.9271	590.6804		

**Table 5: Cellular toxicity effect of study samples on L929 cell line by MTT assay.**

Concentration (µg/mL)	DP	DPAgNPs	DP AuNPs
20	95.42 ± 0.011	95.98 ± 0.008	94.15 ± 0.011
40	93.85 ± 0.011	94.97 ± 0.002	92.67 ± 0.002
60	91.84 ± 0.005	93.41 ± 0.013	91.15 ± 0.002
80	91.13 ± 0.005	92.51 ± 0.009	88.12 ± 0.003
100	90.13 ± 0.008	89.68 ± 0.004	87.9 ± 0.002

**Table 6: One-tailed ANOVA of Sample groups for Cytotoxicity effects on L929 cell line.**

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	16.3634	8.1817	1.3557	0.2946
Error (within groups)	12	72.4206	6.0351		
Total	14	88.784	6.3417		

## CONCLUSIONS

Nowadays, modern pharmacologists have turned to traditional and classic medicinal approaches for deriving multi-potential bioactive compounds to encounter a wide range of diseases and physiological disorders. In this research, the anti-oxidant potential and cytotoxic effects of a crude ethanolic extract of *Andrographis paniculata*, diethyl phthalate, silver, and gold nanoparticles synthesised using diethyl phthalate were evaluated, and the outcome revealed the improved anti-oxidant activity achieved from DPAGNPs compared with other test samples against both radicals (DPPH and phosphomolebdenum). It was also demonstrated that DPAGNPs had a less toxic effect on the L929 cell line among the study samples. The data show that using DPAGNPs for developing drug carrier systems is far superior to using *A. paniculata*, diethyl phthalate, and DPAuNPs alone, resulting in safe and fine activities.

## FUTURE SCOPE

In future, in vivo toxicology studies can be performed to further investigate its toxicity. Further investigations to analyse its biocompatibility of Diethylphthalate with silver nanoparticle as drug carrier system and clinical trials are necessary for discovery of new drugs formulations.

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**Conflict of Interest.** None.

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# TREATMENT OF HISTORY IN HILARY MANTEL'S WOLF HALL

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## ABSTRACT:

The British writer, Hilary Mantel, earns both critical acclaim and bestseller status for her Cromwell trilogy. She is two-time Booker Prize winner for the first two books of this trilogy. This paper highlights the ways in which Mantel handles the historical characters in a lively and interesting manner in her first Booker Prize winning novel *Wolf Hall*.

## FULL PAPER:

Hilary Mantel is Hilary Mary Thompson, born in July 6, 1952 in Hadfield, Derbyshire, England. She has been composing novels for really a long time before her scholarly fame. Her novels showcases her dull mind and complex expertise. She is known especially for her depressingly funny, socially examining books set in an extensive variety of contemporary and historical fiction. The most famous of her all novels, *Wolf Hall* (2009) portrays the growth of Thomas Cromwell, former Lord Great Chamberlain of the United Kingdom. It is praised for its great degree and complex depiction of its characters. It turned out to be a worldwide smash hit and won the Booker Prize. Its sequel, *Bring up the Bodies* (2012), centers all the more barely around Cromwell's part in the defeat of Anne Boleyn, and it too won the prestigious Booker Prize as well as the top honor of the Costa Book Awards. Both of these novels are adopted for stage play by Royal Shakespeare Company in 2013 and it is also made into television miniseries in 2015. In 2020, mantel released her last part of her Trilogy, *The Mirror and the Light*, which accounts Cromwell's tumble from power and his execution. Hilary Mantel had her sad demise on 22<sup>nd</sup> September, 2022 because of stroke.

Hilary Mantel is viewed as the representative of the Post-World War II English fiction writer. Her twelve novels range from the obscurely creative thrill to historically fictitious work. She is thus, the post-modern novelist. Her books though mirrors the comic components, yet she is a serious writer expressing the ethical vision. Her

books depicts her perspective towards life in a hopeful and in most part in a negative way. Her liking for history and historical events enable her to generate praiseworthy works like *A Place of Greater Safety* (1992), *A Change of Climate* (1994), *An Experiment in Love* (1995), *Beyond Black* (2005) and the Thomas Cromwell series.

*Wolf Hall* firmly follows the true history of Tudor Court. The Tudor reign begin with the King Henry VII, who believes firmly that to maintain the power one must keep a strong allies. So he marries his first son Arthur, to the Spanish princess Katherine of Aragon. Arthur passes just four months after his marriage and the second son, Henry VIII is made the King. Henry VIII is strong-willed to marry Katherine, and for that he gains a special ecclesiastical order which would permit him to wed his sibling's widow. Unfortunately, Katherine fails to give him a son and the only child left for them is Mary Tudor.

*Wolf hall* is set up in the England of 16<sup>th</sup> century. King Henry VIII is trying hard to divorce his wife Katherine and wed Anne Boleyn, but as Catholic Church believes marriage to be long-lasting and permanent, it does not support him for his divorce. Thus, he breaks away from the clutches of Roman Catholic rules and declares himself as the supreme head of the church and the country. He did this with the assistance of his self-determined and skillful minister, Thomas Cromwell, who is the protagonist of this historical novel. *Wolf Hall* begins with his humble, poor life as a child of blacksmith to his prosperity to rise as a lawyer and a legal adviser to the king himself.

Mantel has been evaluated as a hazily fanciful narrator. Her books range from confusing thriller to dark humor and to historical novels. She focuses mainly on family life, seclusion, the idea of time, feminism, religion, the outcome of the political and social framework. In this way she manages a variety of themes throughout her novel.

The *Wolf Hall* begins with the scene of Thomas Cromwell as a child being beaten mercilessly by his father, Walter. The scene makes it clear about father's brutality towards his only son. Everyone sympathize over the future of Cromwell and the thing that it is better for him to leave the house than to tolerate beatings. Thomas, too feel it as the proper solution and leaves the house. In France, he learns three card game and helps the lowlanders, where he learns good and miserable side of life. His only longing is to get enlisted in the military to be an officer: "he walks around the docks saying to people, do you know where there's a war just now?" (Mantel 14). Cromwell from the very young age dreams of achieving a great height.

*Wolf Hall* cherishes, recollection of childhood memories which plays an essential part in the evolution of the characters as well as the plot of the novel. Thomas Cromwell, is seen recalling his sad miserable life, which caused him to leave his house and achieve on his own. *Wolf Hall* also has the description of King Henry VIII thinking of his lost blissful childhood: "I lived at the palace at Eltham, I had a fool called Goose" (Mantel 618). Queen Katherine too recalls her childhood multiple times.

The novel portrays that, people of Tudor court are exceptionally ambition to snatch power, even if it is through their double dealing or through defilement. When King Henry VIII realizes that the church won't give him a divorce, he nullifies the power of the church and declares himself as the supreme head over all the churches. Anne Boleyn with her timid diplomacy, secures the favor of the King and earns high posts for her brothers and father. She also remains strict on the notion that before beginning the relationship, King Henry VIII must legally marry her.

Cromwell is an intellectual man. He is fully aware that men wear mask to hide their own identity. One must be very careful and always find out what people wear under their clothes. That is, one must be careful towards others motifs. Thus, he keeps a close eye on people's defiance and reservations to execute his plans at the right moment. To earn the favor of the king, Cromwell disregards his own principles and satisfies all the cravings of the King. Cromwell knows that Cardinal Wolsey is powerful only till he satisfies King's desire. Wolsey's power and nobility disappears at the King's dismay, which teaches Cromwell that he should have the King's aid to rise in court. As needs be Cromwell is ready to continuously oblige to the King even when he is ethically against to what King is doing. When Henry request the King to prosecute Thomas More for a wrong doing which he didn't carry out; Cromwell shows no opposition. Thus, Cromwell's ambition combined with his important skill assists him to climb to the high position in the King's court.

King Henry VIII is an ardent devotee of Roman Catholic Church. He, thus wants to nullify his marriage with the papal support. He waits for twenty years to get a male heir. If Henry VIII fails to produce a male heir then there is a chance of Civil War. It is because of this that he marries six women; namely Katherine of Aragon, the mother of future Queen Mary I; Anne Boleyn, the mother of Future Queen Elizabeth I; Jane Seymour, the mother of future King Edward VI; Anne of Cleves; Catherine Howard and Catherine Parr.

Marriage, thus plays a major role in *Wolf Hall* as the story revolve around the dissolution of one marriage and legitimization of another marriage of Henry VIII. Katherine who doesn't want to divorce the King, plays all her cards till Cromwell persuades her advantages saying that, her daughter Mary will be made the Princess and she will get a decent sum of wealth for her living.

Anne Boleyn who the King needs to marry, likewise is been anxious to become the Queen of England, which is impossible unless she legally marry the King. She feels the vulnerability and uneasiness about her marriage. As their secret marriage is fixed, there fosters another problem, one Harry Percy claims that he has covertly married Anne and she is his lawful wedded wife and the King can't marry her. It is Cromwell again who decides to dispose of this case. In a public gathering where King needs to get the public consent to his marriage, a nun, Elizabeth Barton, shows up and predicts the destruction of the Kingdom if he marries Anne. Anne at this time keep a close watch on the individuals who support her and individual who go against the marriage. The people assisting their marriage were heavily rewarded and the rivals where tormented after she legally became the Queen.

In the beginning of the novel, the castle of Cardinal Wolsey is being vacated and he is being ordered to return back the great seal of England, which is his power of authority. He is shifted to Tower, which is a place of torment. This embarrassment of Wolsey gives Thomas Cromwell a tricky idea of revenge. He, thus intentionally draws near to the King so that he can do the things all the more without any problem. He sends Cardinal Wolsey to north and instead of going with him, he sends Rafe and Richard to accompany Wolsey. Meanwhile he is working to become more close to the King. Cromwell plots vengeance against all who are responsible for Wolsey's condition. Among them he needs to diminish the significance of Stephen Gardiner, Henry Norris, Harry Percy, Duke of Norfolk and Duke of Suffolk and some others. At a certain point of time, after becoming the counselor of the King, he puts before the House of Commons a bill to suspend the money to be deposited to Rome. This is a plan of Cromwell to show the King, his true supporters. Thus, King finds out who all are for him and who all are against him. He does it cunningly. At this point he forces to desert the Stephen Gardiner from his house in the name of Anne Boleyn. He thus, outsmart every individual in plotting revenge. He works cunningly like a wolf. King Henry has praised him saying that he is as clever as a bag of serpents.

The theme of childhood, ambition, religion, marriage etc. in *Wolf Hall* leads to a major theme, transformation. The protagonist, Thomas Cromwell, a son of Blacksmith transforms into a strong and powerful man. He elopes at the age of nine to escape his father's beating and comes back only twelve years later with a wife, Liz. He gets an opportunity to work with Cardinal Wolsey which paves him a way to become close to king and he with his talent emerges as a Counselor to the King, then becomes a keeper to the jewel house. He later replaces Stephan Gardinar and becomes a master Secretary. Then, becomes King's deputy in church affairs too. *Wolf hall* thus, is the story of transformation of Cromwell, which Hilary mantel showcase in an amazing and trustworthy way.

Hilary Mantel is noted for her thematic diversity:

Diversity of theme is the main characteristic of novels of Hilary mantel. There is no one connection in Hilary Mantel's two novels, in respect of theme. Even the sequel of Thomas Cromwell's trilogy novels has different themes *Wolf Hall* deals with rise of Thomas Cromwell from a son of a poor blacksmith to King Henry's right hand. The sequel of this novel *Bring Up The Bodies* is about beheading of Anne Boleyn and Cromwell's avenge on his enemies. (Deokar 18)

She has uniqueness and writes each novel with the unique theme.

Hilary Mantel makes clear her 'novelistic vision'. She states life itself is unstable and so we are. If one tried to be stable then he or she would be finished. Therefore, Hilary mantel hates monotonousness in writing and wants choice. (Deokar 201)

The theme of *Wolf Hall* is vastly distinct. When Thomas Cromwell and Thurston, his cook, discuss Cardinal Wolsey and Norfolk, they discuss the historical concept that "man is wolf to man". This is the central theme of

this novel. The main characters in this novel are trying their hardest to stay in power in the English court by any means necessary. Man has transformed into a wolf in this circumstance.

Although *Wolf Hall* is a historical novel, as a piece of fiction it offers a relatively accurate insight into the lives of people living in the Tudor period. Through this novel Hilary Mantel paints a picture of people in Tudor England. She does not provide a historical factual record that fits stereotypes; but also describes how English people used to think and act during that time. During this time, aristocrats, kings, queens, and even priest has a tendency to say that man is wolf to man. Characters and incidents in the current novel demonstrate the same trend. The saying, man is a wolf to man means, the man acts like a wolf towards another man for his own benefits. King Henry wants to marry Anne Boleyn and divorce his first wife in order to produce a male heir. Yet, Pope of Rome doesn't permit him to do as such. The idea of a male heir is the King's obsession. He captures Cardinal Wolsey and imprisons him for treason, where he dies. By punishing Cardinal Wolsey, the King hope to instruct the Pope. Thomas More, who disagree with the King's status as head of the Church of England, and he too is beheaded by him. King Henry thus, transforms into a wolf and kills his enemies to fulfill his wish. Anne Boleyn needs to wed King Henry and she too becomes like wolf and is ready to kill anyone who gets in the way of her in becoming the Queen of England. The theme of man is wolf to man oozes throughout the novel revealing the Tudor's tendency.

The characters portrayed by Hilary Mantel have not been depicted in historical context. She has however reinvented them. She has shown the readers what goes on inside these characters' heads. The phrase "man is wolf to man" serves as the novel's overarching historical theme. The main characters in the novel use both good and foul tactics to gain or maintain power in English court. The current novel has a very straightforward plot, in order to make it easier for readers to comprehend the serious historical novel and keep them interested in reading. *Wolf Hall* thus is definitely a work that bought fame and recognition to our late writer Hilary Mantel.

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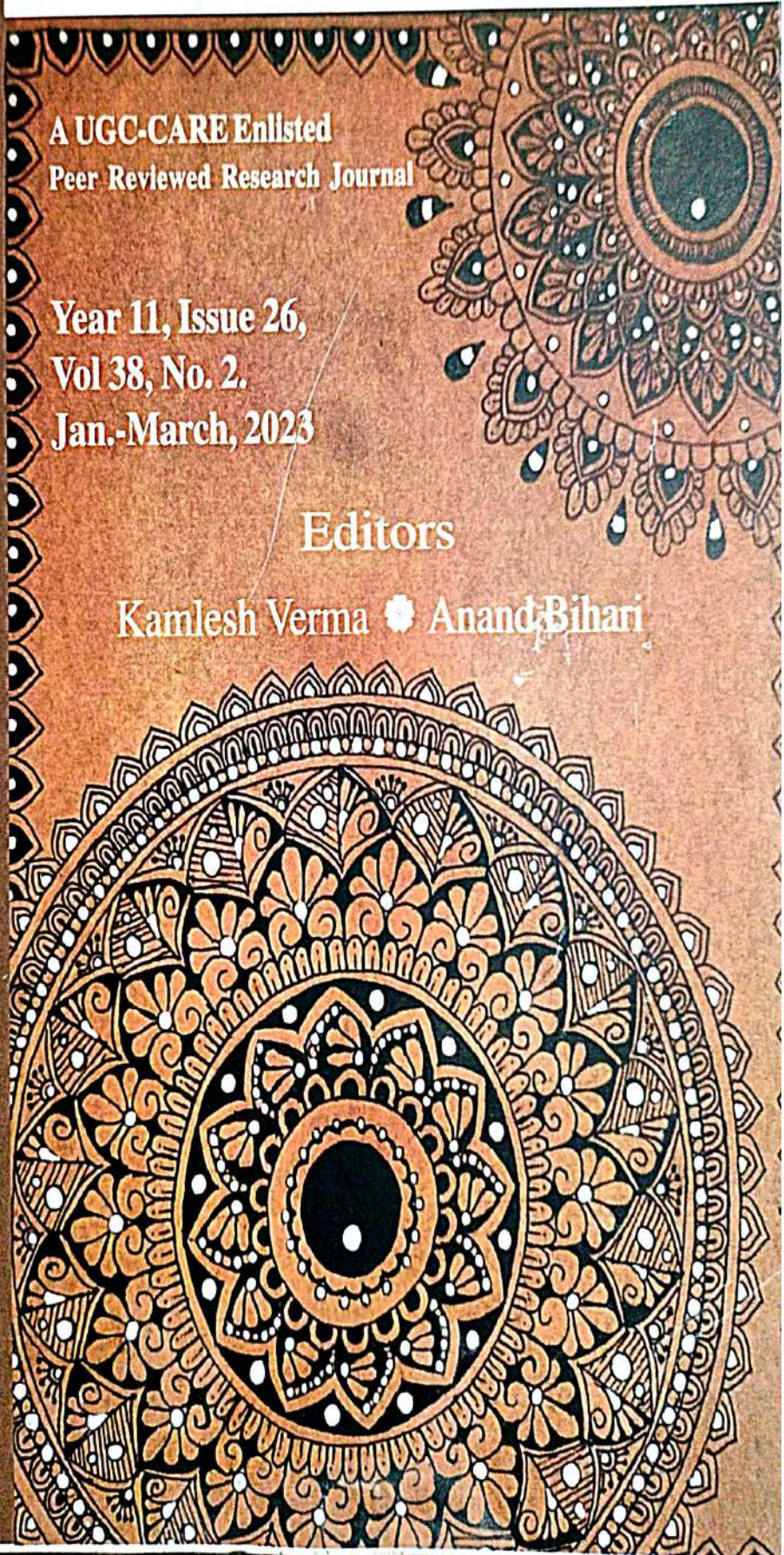
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# Importance of Marriage Ideals in Premchand's *Gaban*

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## **Abstract**

In Indian society marriage is considered as the most important relationship. Mutual understanding, love and care are some of the important factors, which are necessary to keep the marital life strong. In *Gaban*, Premchand has depicted the problems in the marital life of the couples, which can destroy marriages.

**Keywords :** Family, Marriage, Middle class society, Jewels.

Marriage is considered the most important sacred bond, between husband and wife since ancient times in India, which brings together a man and a woman, and connects them together for life time through sacred rituals. Family is an important link between a human being and society. Marriage is all about husband and wife living together with mutual understanding to create a family. But for the achievement of this understanding there should be compatibility among husband and wife.

Indian culture is very rigid about its age old norms. Premchand felt deeply that the age-old social norms of marriage are rotting the society. He criticized mismatch in marriage, dowry system and child marriage. These issues led to disparity among the husband and wife, which in further destroyed the peace and serenity of marital life of couples and led to unhappiness in the families. Premchand in his stories and novels has portrayed all the anomalies present in marital life. Thereby, people will save themselves from these malpractices. Premchand who was against all these malpractices had joined Arya Samaj which was rebelling against all these problems.

Premchand in his writings eulogized the marriage ideals. If husband and wife are not able to follow the ideals of marriage, then their marital life suffer, which in further leads to

discord in the family. He wrote about the problems, which degraded the sacredness of marriage, with an aim of readers becoming aware of it.

*Gaban* looks upon the problems prevalent in the middle-class society; people of this class always suffer from a sense of low self-esteem, as they are not able to afford what they want. They aspire to be like upper class society people. The problem with the people is that they are not able to work out their life with what little they earn. There is a want among them to have more than what they can afford.

The story of the novel begins in Allahabad. The story revolves around the life of young couple Jalpa and Ramanath. It tells about the plight of middle class couples who are entrapped inside the vicious circle of vanity. Instead of being satisfied with what they have, they destroy their own peace, in their greed for more. Ramanath and Jalpa are best example of it.

Dindayal and Dayanath belong to middle class families. Dindayal as an agent of a landlord has a meagre income of five rupees per month, which was not enough for running a family. He had other sources of income, from where he got money, which are never mentioned. His daughter Jalpa, at an early age develops a craze for jewellery, and is assured by her elders that during her marriage she will get her favourite piece of jewel (Chandrarahar) from her groom. Dayanath, a father of three sons, worked in the court, he was an honest man, and he somehow managed to take care of his family with his income of fifty rupees per month. His eldest son Ramanath is a carefree person. Dayanath was not able to send him for further studies due to lack of money. That didn't matter to Ramanath, because he never took life too seriously. His life is totally built up on the foundation of lies. Dayanath hesitates in getting Ramanath married, because "to marry off someone who doesn't even concern himself about where his next meal is coming from" felt wrong to him (*Gaban*5).

He wants to live a life of extravagance. He enjoys himself by moving around extravagantly through help of his friends. Ramanath represents weakness of the middle class society. He runs away from his responsibilities and thinks illusions created through lies are good. He is morally a weak person. He wavers in taking decisions till the end.

Jalpa and Ramanath's marriage takes place without any problem of dowry unlike in the case of most of the marriages. But Dayanath spends too much on marriage celebrations, much more than the money he had. He buys jewellery on loan, for which he is not being able to pay back. Therefore Ramanath steals Jalpa's jewels and gives it to the jeweller. He lies about his family's true conditions to his wife. After he gets a job in the municipality office through his friend Ramesh, he lies about the income to his wife. He starts getting decent salary but is not able to save any, even though he took bribes from the office. Because, he boasts in front of his wife and to make her happy he spends extravagantly. He buys jewellery for her on loan, thereby, gets in high debt. He lies to Jalpa's friend Ratan, about the price of Jalpa's bracelet and by mistake ends up spending her money also. To escape from problems he tries to use office money (with no intention of embezzling it). Which, Jalpa unknowingly gives to Ratan. Thereafter, Ramanath feeling unable to put back the office money gets a fear of embezzlement case against him, therefore he runs away to Calcutta.

In Calcutta, police arrests Ramanath on suspicion of another case, scare him with



false charges (since no actual embezzlement had happened) and forces him to become a false witness by bribing him with money and job. He being a morally weak man falls for it. Thereby after getting trapped in devious games of police, he gives false testimony. Jalpa when gets to know about it, is furious with Ramanath's cowardliness.

When Ramanath used to buy jewellery for her, she in her obsession of jewellery used to become more devoted to him. But that doesn't mean her character is limited to the typical image of a middle-class woman with love of jewellery. She has self-respect and moral strength also, as she returns her mother's jewellery, which is sent to her when Jalpa's jewellery gets stolen, she vehemently says, "I won't take charity from anyone, even my own mother" (*Gaban* 39).

When Jalpa gets to know the truth about the actual financial condition of Ramanath, she regrets her own behaviour, a new change comes within her and her true devotion towards her husband comes to the fore as she happily sells off her favourite jewels to return the office money and pay off the debt. Jalpa likes jewellery but that doesn't mean she doesn't love her husband. When she learns about the true condition of her husband, she sacrifices her attachment to all the splendour and luxury and comes out as a devoted wife. It is Jalpa who puts a lot of effort to bring her husband out of his erroneous path.

There is marital love between Jalpa and Ramanath, but it lacks trust and devotion. In marriage happiness can be achieved only through understanding and truth. He gets in trouble because of the lies he thought would protect his conjugal life. Jalpa in her cravings for jewellery never tried to analyse the financial condition of her husband. Situation wouldn't have taken a wrong turn "[if] Jalpa had been able to hold herself steady through the stormy blasts of her cravings, if Rama had not yielded to his embarrassment" (*Gaban*68).

He hesitates in making decisions and behaves like a coward. He himself creates troubles for himself, and then feels incapable of facing them. Apart from all these negative traits, he has some redeeming qualities also. Hisson like affection towards Devidin, and his wife Jaggo (without paying attention to the fact that they, belong to a lower caste). And most importantly his unending love for Jalpa.

Ramanath is a morally weak person, and Jalpa is infatuated with jewellery, which she is able to overcome because of inner strength, her pure love and concern for her husband. This is something which Ramanath lacks. In the end after all the trials and tribulations, when both reject show off and love of luxury, they are able to enjoy the true bliss of married life. Trial was necessary to cleanse them of all the faults so they are truly prepared for a true bond.

Another problem is of incompatible marriages prevalent in the society. Premchand had critiqued unmatched marriages in his other works like *Nirmala* and *Sevasadan* also. As he had to go through one in his own life as Amrit Rai points, "His own father remarried at an old age and left behind a widow and a little son" (38). Not only that "he himself had been married off at a tender age, and had to bear at first the responsibility of making a go of an utterly incompatible and awkward match, and later the guilt of failing to do so" (38).

Ratan has a mismatch marriage with a much older widower Vakil Sahib. After the death of her parents, Ratan's uncle gets her married to Advocate of Allahabad's High Court, Indra Bhushan. Ratan respects Vakil Sahib and he treats her with fatherly affection.

He buys for her everything she wants. But there is no husband and wife love between them. They respect each other's feelings. But somehow it lacks mutual understanding. He is not able to foreshadow the troubles; she will have in future, if he doesn't give her, her share of property. Even when he is very sick, he also like Ramanath wavers in taking decision. Towards the end of his life, Vakil Sahib with a full knowledge of legal system didn't settle anything for his wife for her secure future.

She had sacrificed her youth for him, as she herself tells Jalpa "I never even thought that I'm a young woman and he's an old man" (*Gaban* 137). She also liked jewellery like Jalpa. She had everything in terms of luxurious life, she enjoyed herself in roaming, buying things and parties. Her luxurious life quelled her anxiety related to marriage. But everything is destroyed when her husband's nephew Manibhushan through his deviousness usurps everything, after his death. Ratan thinks that she will be able to survive, without her husband. But as a widow she has no place in the society, no identity without her husband, and no place in her husband's family, because after husband's death as she says in anguish, husband's family "is not a bed of flowers for you, but a bed of thorns" (*Gaban* 245).

The other couples whose marriage the novel gives us glimpse of is Devidin and Jaggo and Dayanath and Jageshwari. Dayanath is an honest man, in his many years of government job he never took bribe, his wife Jageshwari is not enthusiastic about this behaviour of his, since she acutely feels the poverty they are in. she is remorseful of the fact that even after all the struggles she has faced in bringing up the family, her little desires also never got fulfilled.

Then there is Devidin and Jaggo, who also have different temperaments, except for the love of their dead sons and their affection for Ramanath. Devidin is a man who believes in simple living unlike his wife who has a craze for jewellery.

Like Devidin and Jaggo, both Dayanath and Jageshwari also have different opinions on matters. But these old couples have a strong relationship as they stand out for each other in times of need. For a successful marriage Premchand through this novel has represented that, there should be understanding and compatibility

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पद्म भूषण पंडित सामता प्रसाद ट्रस्ट ऑफ तबला की अध्यक्ष व मेरी परम श्रद्धेय माँ श्रीमती शकुन्तला जौहरी ने दिनांक 25/03/2023 को अपना पार्थिव शरीर त्यागकर परलोक गमन किया। 'कुतप' शोध पत्रिका का शुभारंभ उक्त ट्रस्ट के आधार पर ही हुआ है। अतः ट्रस्ट व कुतप परिवार की ओर से माँ को भावभीनी श्रद्धांजलि प्रेषित है व पूर्ण विश्वास है कि सूक्ष्म जगत से आपका आशीर्वाद व प्रेरणा सतत मिलती रहेगी। इहलोक व परलोक का सम्बन्ध जुड़ा रहेगा। आपको नम आँखों से कोटिशः नमन वंदन करती हूँ।

## Editorial

This is VIIIth issue of 'Kutap' Journal. This is a special issue in terms of variety of readings. There are three chapters in this particular issue. First one is based on music & interdisciplinary. From an International Seminar titled 'Promotion of Indian Language, art and culture regarding' National Education policy 2020; which was held on February 10th and 11th 2023, organized by Music and Performing Arts Department, University of Allahabad, 10 best research papers have been selected for this issue of Kutap and placed in chapter IInd. chapter IIIrd has included research paper of Arts & humanities from



Arunachala College of Engineering for Women, Kanyakumari, district Tamilnadu. Communion of North, East, West & South through vast ocean of knowledge is the first & foremost aim of the formation of the Journal Kutap. For readers, there is an adequate amount of material to nourish their brain. This special issue is dedicated to my beloved, great mother Smt. Shakuntla Johri, who inspired me to start Kutap Journal. She left us for her heavenly abode on March 25th 2023. My heartfelt Naman to her.

I tender my Heartfelt wishes & congratulations to all authors for their valuable contribution.

Thanks and Regards

**Prof. Renu Johri**

Head

Dept. of Music and Performing Arts  
University fo Allahabad



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## Depiction of Oppressed Peasants in Premchand's *Godaan*

Amala Thomas\* & Dr. D .Joen Joselin†

**Abstract**—Munshi Premchand was always at his best when it came to writing about the village life. The present study deals with Premchand's portrayal of suffering of peasants in the village through his work *Godaan*. Through the character of Hori, Premchand explores the various factors which lead to peasants' deplorable condition. Is it external or internal? This work tries to analyze the problem.

**Keywords:** Peasants, Gandhian ideology, Progressive, Village, Rural, Urban, Colonialism

Dhanpat Rai Srivastava (13 July 1880 - 8 October 1936), known by the penname Munshi Premchand, is the most acclaimed writer of Hindi-Urdu literature. Premchand was also a prominent member of "All India Progressive Writers' Association", which was formed in India in 1936. *Godaan*, which is considered a masterpiece among his writings, was published in 1936, it was also the last novel he wrote.

*Godaan* was written around at the time when, in India, national movements for independence were running in full swing. He never took active part in national movements, but he believed that, as a writer he could bring about change through his works. Premchand was a writer of the people. He was very sympathetic towards the down trodden people of the society. He believed in the writer's role as a social reformer. He was a firm believer in literature as a tool in bringing change by projecting the reality of the society to the readers.

This novel epitomizes his ideas and shows the stark reality of struggling peasant class. The novel looks upon the lives of the people living in the city of Lucknow which was Awadh's capital, and Belari and Semari, the two villages in the province of Awadh. Hori the tragic hero of the novel, symbolizes the peasant class of India, and their never ending battle against poverty as they are constantly subjugated by the ruling class. Hori a poor, hard working peasant from the village Belari, has only one simple dream in his life, which is to own a cow. Even though, Hori and his wife Dhaniya work hard, day and night, it is never enough to even provide a proper meal in the family. Hori, like other peasants in his village is always in debt, because of family commitments, and especially moneylenders' callousness. He never questions or resist, against the cruel traditions and customs which he knows are the cause of his misery. He easily gives in to the words of the exploiting moneylenders. He has blind faith in destiny. In the end Hori dies, without having his dreams fulfilled.

Premchand in his works focuses upon the social and economic conditions of people of that time, especially in *Godaan*, the peasant class. As many critics have also pointed out Premchand is at his best when he depicts the rural society. As Prem kumar has pointed out, "Premchand was born and raised in a village and he best understood life in rural surroundings. Although he spent a considerable portion of life in various cities, he had recognized early in his career that India was essentially a rural society, and that any attempt at reforming India must focus on the village" (67).

Both city and village are presented in a stark contrast with each other in his writings. Peasants in colonial India are shown to be doubly subjugated because of the colonial and feudal system, who with their capitalistic interests, had broken the spirit of peasant people. The main center of this exploitative culture, was epitomized as being the city with its decadent urban culture. As we see especially in *Godaan*. City people as seen in the novel, are corrupt and selfish, as showcased in the characters like Khanna (the industrialist) and Rai Sahib (the feudal landlord), who are the epitome of moral decay, as their only motive in the entire novel is to squeeze money out of poor working class people. Even some characters like Professor Mehta, Miss Malti, Mirza Khurshed and Pandit Onkarnath, with their high talk are not shown to

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be doing anything fruitful for the poor people.

This depiction coincides with the Gandhian philosophy of rural-urban dichotomy. During his lifetime apart from socialist ideology, Premchand was also influenced by Gandhi's social outlook. Premchand, for a time, was a follower of Gandhian ideology of thought, according to which, he also felt that elite classes of urban areas had a parasitic nature towards the poor peasants, and city culture was an extension of British imperialistic ideology. As P.C. Joshi points out "Gandhi saw in the town-village confrontation a major expression of the irreconcilable cleavage between Indian nationalism and British colonialism" (46), not only that, Gandhi also believed in as Joshi further says in the "non-class concepts of 'change of heart on the part of propertied classes and of 'reformed' and 'good landlords' as trustees of peasants" (45). Premchand incorporated these ideas in his earlier novels. For e.g. in *Karmabhumi*, city comes across as a place only for rich people. Selfish and arrogant; these elite city people exploit the working people for their own gain. But in the end there is change of heart in many of these wealthy people. In *Gaban*, as Kumar points, the main characters at the end fed up with their city life "go and establish a utopian community by the river Ganges away from the corruptions and degradations of city life" (71). In *Sevasadan* too we come to see moral decaying in the city of Benaras, where the main protagonist Suman, falls prey to false enchantment of the life of prostitution.

In the novel *Godaan*, rural and urban society with its characters, are kept apart, with Rai Sahib and Hori's son Gobar being the connecting links. City's evil influence can be seen through changes in Gobar's behavior. Gobar was always rebellious, but he always used to respect his parents. His stay in the city changes him a lot, which is seen after he returns the village. He becomes disrespectful towards his parents and elders in the village, and having acquired some money in the city, he becomes very proud. When he returns to city with his wife Jhuniya, their lonely existence is quite visible, unlike in the village, where close ones are always there to support.

Even if Premchand had adhered to the Gandhian philosophy in the earlier writings, he goes beyond that in *Godaan*. As Joshi points "Premchand, did not allow himself to become a prisoner of Gandhi's backward looking idealization of the village and denigration of the town" (43).

Premchand has taken a more critical stance in his outlook to the peasant suffering, and as Joshi says "Premchand no longer focus on the 'enemy outside' the village" (53). A deeper look gives us an understanding that there is more about the problems of peasants' suffering. It is true that the city dwellers have shallow outlook towards the peasants. But the peasants are to be blamed themselves for their situation as they are not willing to stand up for themselves and are ready to be victimized by the backward traditions and social ideologies which help the corrupt people like village superiors (the moneylenders) to victimize the peasants, by using their gullibility.

Premchand in *Godaan* moves away from the Gandhian ideology of villages being the idealistic place, and the idea that, change in social order is possible through change of heart among elite class. Premchand shows problem in Hori's fatalistic behavior and his meek adherence to the prevalent social order and norms, along with that, village elite with their unquestioned power, strangle the dreams of the peasants. Hori is too meek and submissive and never questions the traditions. In a way he can be blamed for his own tragedy.

It is true that the rural society has taken the whole sympathy of Premchand, in terms of its suffering peasant class and city does not. He also believed in the village community's sanctity. Especially, the fact that their harmonious life is being crushed by the elite class living in the city. We also feel pity for a poor peasant like Hori who dies miserably. But he doesn't idealize the village society; also he wants to show the stark reality of that time, in which he has been writing.

It's only Gobar who stands for himself, even though his future is not clear in the end. But it's for sure that he won't follow the suffocating ideas of the society. Hori's sad death in the end of the book fills the readers with a sense of hopelessness, through Hori's plight, the writer questions the social system, and wants to make the people realize, the dilapidating conditions peasants are living in, and how much

necessary it is to bring change in the society.

The writer's intention is focused on understanding and criticizing the problems prevalent in the society. This can be eradicated, only if the people understood it in full gravity. The book questions the degrading conditions of the poor peasants, which is still prevalent in the society. Premchand emphasizes a total change in the society.

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**Relationship of Selected Anthropometric Measurements Physical Fitness  
Components and Physiological Parameters Highly Correlated  
with Sprinting Ability of Inter-Collegiate Sprinters**

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**Abstract**

The intension of the study was to investigate the selected anthropometric measurements, physical, physiological parameters highly correlated with sprinting ability of inter-collegiate level sprinters. To attain this aim, the investigator selected 330 male inter-collegiate level sprinters as subjects. Random group design was used for this investigation, as it is most suitable. The age of the selected subjects was from eighteen to twenty five years. In this study one criterion (sprinting ability) and sixteen determinant variables were included. Pearson product moment correlation was utilized to verify the association between criterion (sprinting ability) and determinant variables. The relationship between criterion and determinant variables as well as inter-correlations among determinant variables was calculated by using Pearson product-moment correlation formula. To test the hypothesis 0.05 level of confidence was fixed. The sprinting ability (SA) is significantly correlated with height, arm length, leg length, thigh girth, calf girth, speed, explosive power, muscular strength endurance, dynamic balance, breath holding time, VO<sub>2</sub>max and anaerobic power of the sprinters.

**Keywords:** *Anthropometric, physical, physiological parameters and sprinters*

**INTRODUCTION**

The superior performance of today's athletes is the result of a complex blend of many factors (MacDougall et al., 1991). These factors include genetic endowment, physiology, biomechanics, training, health status, and experience. Champion athletes, depending on their specific sports, vary considerably in their physiological attributes (Daniels, 1974). It is therefore necessary to gain an understanding of the essential performance characteristics of a specific sport, in order to develop optimal training strategies for the athlete.

Sprinting is running over a short distance at the top-most speed of the body in a limited period of time. It is used in many sports that incorporate running, typically as a

way of quickly reaching a target or goal, or avoiding or catching an opponent. Sprint running races are short distances races in which athletes try to run at their maximum speed throughout the entire distance of the race. Sprint races are part of the track and field discipline and are included in all events that feature track and field competitions. Three sprints are currently held at the modern Summer Olympics and outdoor World Championships: the 100 metres, 200 metres, and 400 metres.

As compared to other sprinting events, the relative simplicity of the 100 m sprint makes it ideal for studying the elements of sprint running. Unlike other track-and-field sprints, such as the 200 m or 400 m event, the 100 m sprint does not involve a curve of the track. Thus, running technique involves purely linear movement, and no centrifugal or centripetal (outward and inward radial) forces. Given recent world record accomplishments in the male 100 m sprint event, it is assumed that a review of this event, and the multiple determinants to 100 m sprint performance would be a timely addition to the scientific and coaching literature within athletics. Consequently, the purpose of this study was to identify the features of the 100 m sprint that make it such an iconic event, and summarize the multi-faceted determinants to sprint running performance so that understanding and commentary on performance can be based on science rather than speculation or personal bias. Taking this into consideration the research scholar has decided to conduct his research on the same and find the solution of the problem. This research will be useful for both sprinters as well as coaches to improve sprint performance.

## **METHODOLOGY**

### **Selection of Subjects**

To determine the association between the criterion and determinant variables, three hundred and thirty male inter-collegiate level sprinters from various arts and science colleges affiliated to Manonmaniam Sundaranar University, Tirunelveli and also from Madurai Kamaraj University, Madurai, Tamilnadu were chosen. Random group design was used, as it is most appropriate. The age of the subjects was from 18 to 25 years.

### **Selection of Variables**

**Criterion Variable:** The 100m sprinting performance of the selected sprinters were considered as criterion variable.

**Anthropometric Measurements:** The following anthropometric variables namely Height, arm length, leg length, thigh girth and calf girth were selected.

**Physical fitness components:** The physical fitness components such as maximum speed, explosive power, muscular strength, flexibility and dynamic balance were selected.

**Physiological parameters:** The physiological parameters such as resting heart rate, breath holding time, anaerobic power, forced vital capacity and  $Vo_2max$  were selected.

### Collection of Data

The sprinting ability of the subjects was assessed by conducting 100m race and the selected anthropometric measurements, physical fitness components and physiological parameters were measured through standard test and measurements.

### Statistical Techniques

In this study one criterion (sprinting ability) and sixteen determinant variables are included. Pearson product moment correlation was utilized to verify the association between criterion (sprinting ability) and determinant variables. The relationship between criterion and determinant variables as well as inter-correlations among determinant variables was calculated by using Pearson product-moment correlation formula. To test the hypothesis 0.05 level of confidence was fixed.

### Result

The descriptive statistics– range, minimum, maximum, mean and standard deviation of anthropometric, physical, physiological parameters and sprinting ability of sprinters have been presented in table-I.

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Height	330	15.00	154.00	169.00	1.6099E2	4.18311
Arm length	330	15.00	54.00	69.00	60.9939	4.18202
Leg length	330	10.00	69.00	79.00	75.0636	2.82287
Thigh girth	330	9.00	39.00	48.00	43.2333	2.72723
Calf girth	330	7.00	25.00	32.00	28.5030	1.56762
Speed	330	0.84	4.14	4.98	4.5257	.14345
Power	330	50.00	2.00	52.00	45.2030	4.16141
Strength	330	10.00	59.00	69.00	64.9455	2.77035
Flexibility	330	6.00	12.00	18.00	15.2576	1.82777
Balance	330	8.00	35.00	43.00	39.0636	1.96138
RHR	330	3.00	65.00	68.00	66.4758	1.19816
BHT	330	31.00	37.00	68.00	40.33	2.55
Anaerobic	330	26.00	260.00	286.00	2.7523E2	5.53767
FVC	330	0.54	3.05	3.59	3.3423	0.15795
$Vo_2max$	330	0.31	2.64	2.95	2.8035	0.09017
Sprinting	330	2.20	11.10	13.30	12.0795	0.61959

### Correlation Analysis

The Inter-relationships between chosen anthropometric, physical, physiological parameters with sprinting ability of sprinters were computed using Pearson Product Moment Correlation and results are given in Table – II.

**Table –II: Inter-Correlation Results on Selected Anthropometric, Physical, Physiological Parameters with Sprinting Ability of Male Sprinters**

	SA	Ht	AL	LL	TG	CG	SP	EP	MSE	Flex	DB	RHR	BHT	AP	FVC	VO <sub>2</sub>
SA	1	0.301*	0.287*	0.318*	0.163*	0.161*	0.229*	0.285*	0.284*	0.053	0.200*	0.006	0.112*	0.619*	0.018	0.394*
Ht		1	0.998*	0.975*	0.599*	0.243*	0.144*	0.736*	0.707*	0.006	0.325*	0.029	0.086	0.394*	0.347*	0.707*
AL			1	0.976*	0.578*	0.250*	0.131*	0.724*	0.691*	0.003	0.331*	0.013	0.098	0.390*	0.341*	0.698*
LL				1	0.467*	0.231*	0.156*	0.688*	0.706*	0.010	0.337*	0.090	0.028	0.383*	0.360*	0.703*
TG					1	0.088	0.217*	0.659*	0.479*	0.060	0.228*	0.275*	0.236*	0.134*	0.133*	0.465*
CG						1	0.308*	0.031	0.108	0.133*	0.265*	0.139*	0.073	0.086	0.141*	0.365*
MS							1	0.155*	0.245*	0.317*	0.106	0.231*	0.178*	0.310*	0.254*	0.185*
EP								1	0.646*	0.071	0.130*	0.149*	0.131*	0.273*	0.309*	0.343*
MSE									1	0.097	0.243*	0.046	0.101	0.117*	0.369*	0.445*
Flex										1	0.183*	0.106	0.076	0.144*	0.282*	0.087
DB											1	0.082	0.160*	0.014	0.050	0.369*
RHR												1	0.912*	0.132*	0.002	0.185*
BHT													1	0.014	0.044	0.053
AP														1	0.328*	0.134
FVC															1	0.261*
VO <sub>2</sub>																1

\*The required table 'r' value is 0.109 at 0.05 level of confidence.

SA	Sprinting Ability	CG	Calf girth	DB	Dynamic balance
Ht	Height	SP	Speed	RHR	Resting heart rate
AL	Arm Length	EP	Explosive power	BHT	Breath holding time
LL	Leg Length	MSE	Muscular strength endurance	AP	Anaerobic power
TG	Thigh Girth	Flex	Flexibility	FVC	Forced vital capacity
				VO <sub>2</sub>	VO <sub>2</sub> max

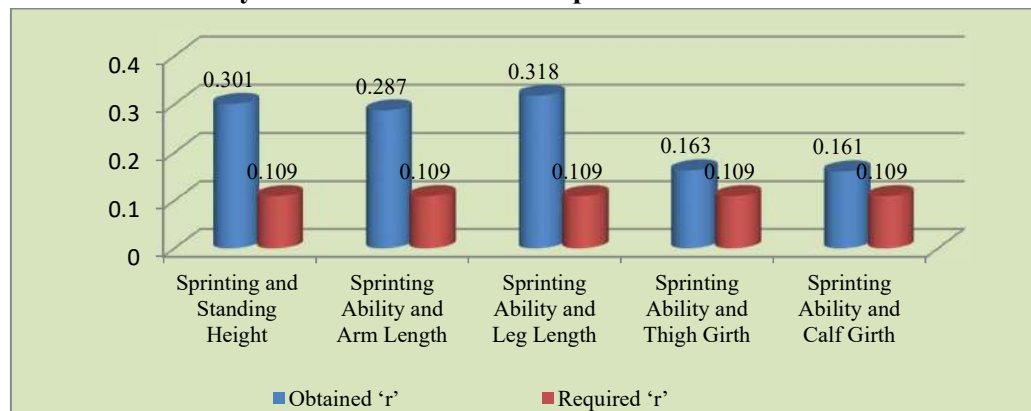
The following anthropometrical variables; height (0.301), arm length (0.287), leg length (0.318) thigh girth (0.163), calf girth (0.161) were significantly correlated with the sprinting ability. High correlation also existed between sprinting ability versus selected physical fitness components namely speed (0.229), explosive power (0.285), muscular strength endurance (0.284) and dynamic balance (0.200). The chosen physiological components; breath holding time (0.112), VO<sub>2</sub>max (0.394) and anaerobic power (0.619) was significantly correlated with the sprinting ability. As the obtained 'r' values was found at 0.05 level of confidence was higher than required table 'r' value 0.109. The obtained and required 'r' values of selected anthropometric measurements with sprinting ability is displayed in table-III.

**Table – III: Correlation between Criterion and Anthropometric Measurements**

S.No	Variables Correlated	Obtained 'r'
1.	Sprinting and Standing Height	0.301*
2.	Sprinting Ability and Arm Length	0.287*
3.	Sprinting Ability and Leg Length	0.318*
4.	Sprinting Ability and Thigh Girth	0.163*
5.	Sprinting Ability and Calf Girth	0.161*

\*The required table 'r' value is 0.109 (0.05 level)

The sprinting ability was significantly correlated with the selected anthropometric measurements such as height, arm length, leg length, thigh girth and calf girth of the sprinters since the obtained correlation coefficient values 0.301, 0.287, 0.318, 0.163 and 0.161 are greater than the required table value (0.109). The obtained correlation coefficient values between sprinting ability and the selected anthropometric measurements are graphically represented in figure-I.

**Figure-I: Diagram Showing the Correlation Coefficient Values between Sprinting Ability and the Selected Anthropometric Measurements**

The obtained and required 'r' values of selected physical fitness components with sprinting ability is displayed in table-IV.

**Table – IV: Correlation between Criterion and Physical Fitness Components**

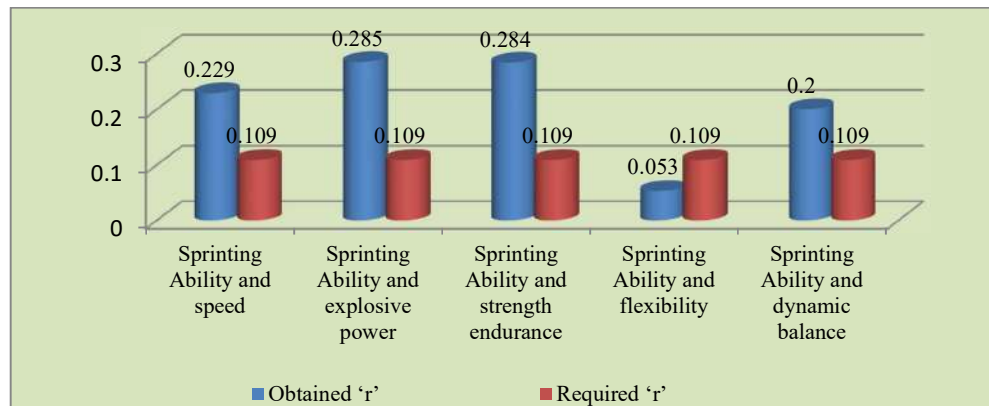
S.No	Variables Correlated	Obtained 'r'
1.	Sprinting Ability and speed	0.229*
2.	Sprinting Ability and explosive power	0.285*
3.	Sprinting Ability and muscular strength endurance	0.284*
4.	Sprinting Ability and flexibility	0.053
5.	Sprinting Ability and dynamic balance	0.200*

\*The required table 'r' value is 0.109 (0.05 level)

The sprinting ability was significantly correlated with the selected physical fitness components namely speed (0.229), explosive power (0.285), muscular strength endurance

(0.284) and dynamic balance (0.200), as the required table 'r' value was 0.109 found at 0.05 level of confidence was higher than obtained 'r' values. However sprinting ability were not significantly correlated with flexibility (0.053) of the sprinters. The obtained correlation coefficient values between sprinting ability and the selected physical fitness components are graphically represented in figure-II.

**Figure-II: Diagram Showing the Correlation Coefficient Values between Sprinting Ability and the Selected Physical Fitness Components**



The obtained and required 'r' values of chosen physiological parameters with sprinting ability is displayed in table-V

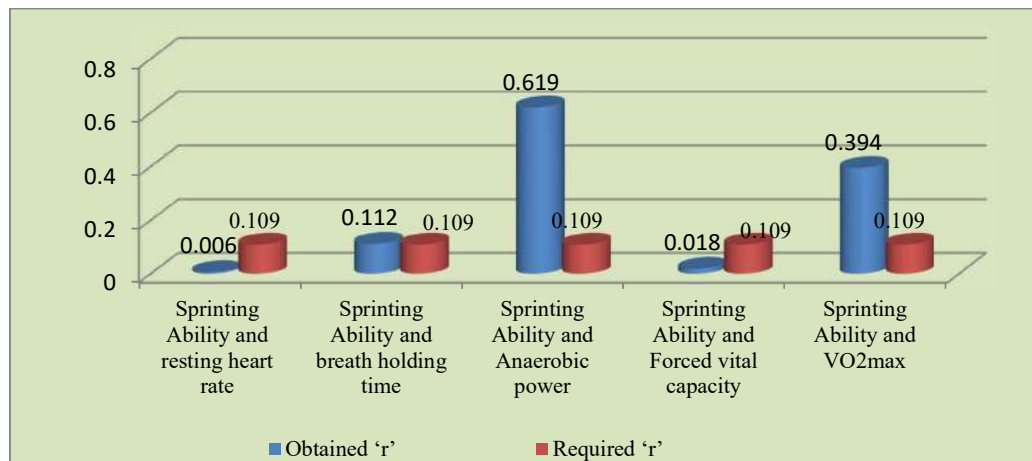
**Table – V: Correlation Co-Efficient between Criterion and Selected Physiological Parameters**

S.No	Variables Correlated	Obtained 'r'
1.	Sprinting Ability and resting heart rate	0.006
2.	Sprinting Ability and breath holding time	0.112*
3.	Sprinting Ability and Anaerobic power	0.619*
4.	Sprinting Ability and Forced vital capacity	0.018
5.	Sprinting Ability and VO <sub>2</sub> max	0.394*

\*The required table 'r' value is 0.28 (0.05 level)

The sprinting ability was significantly correlated with the chosen physiological parameters breath holding time (0.112), anaerobic power (0.619) and VO<sub>2</sub>max (0.394) as the required table 'r' value 0.109 found at 0.05 level of confidence is higher than obtained 'r' values. However sprinting ability was not significantly correlated with resting heart rate (0.006) and Forced vital capacity (0.018) of the sprinters.

**Figure-III: Diagram Showing the Correlation Coefficient Values between Sprinting Ability and the Selected Physiological Parameters**



### Discussion

Ramachandra and Shelvam (2017) identified the predominance of anthropometric variables between the sprinters. The variables in order of priority were standing height, foot breadth, chest breadth, upper leg length, thigh girth, wrist girth, calf girth, weight, ankle girth and foot length. Niels-Uth (2005) compared the anthropometry of sprinters and people belonging to the normal population. Both male and female sprinters had lower body mass index (BMI) than the normal populations. It has been suggested that particular anthropometric measures are pre-requisites for good athletic performance in various sports (Kukulj et al., 1999). The anthropometric dimensions measured in this study revealed significant relationships with sprint performance. Hunter and coworkers (2004) reported that height and leg length to be good predictors of acceleration phase velocity.

High performance sprint running from a block start requires the production of both high level forces and angular velocities (Harland & Steele, 1997; Mero et al., 1983; Mero et al., 1992). Specifically, large forces generated by the leg musculature whilst in the starting blocks can lead to a performance edge over the other competitors in the race (Harland & Steele, 1997). An explosive sprint start requires a powerful angular drive of the arms, hips and legs (Hoster & May, 1979; Korchemny, 1992). An athlete's relative explosive ability of their hip and knee extensors is critical to sprint performance. In fact the stored elastic energy has been suggested to be necessary to sprint performance (Mero et al., 1992).

Human physiology and physique combine to be the most influential determinants of improved sprint performance (Majumdar & Robergs, 2011). Physiological profiling is

used within team sports to assess both the demands of the sport and provide evidence of position specific requirements (Geithner et al., 2006). Differences in positional demands have been found between playing positions, the centre positions being the most active (McManus & Stevenson, 2007). For all athletes involved in high professional competitive sports the body is required to perform at optimum capacity in terms of biomechanics and physiology (Zaccagni, 2012).

### **Conclusion**

The sprinting ability was significantly correlated with height, arm length, leg length, thigh girth, calf girth, speed, explosive power, muscular strength endurance, dynamic balance, breath holding time, VO<sub>2</sub>max and anaerobic power was significantly correlated with the sprinting ability. Present day science is very much interested in estimating the optimum anthropometric, physical, physiological make-up of sprinters. So the scanning and selection of sprinters may be achieved successfully to a great extent by measuring anthropometric, physical, physiological parameters.

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**Relationship of Selected Anthropometric Measurements Physical Fitness Components and Physiological Parameters Highly Correlated with Sprinting Ability of Inter-Collegiate Sprinters**

Authored by

**V. Viju**

From

**Annamalai University**

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## PREDICTION OF THE FACTORS PREDOMINANT TO SPRINTING ABILITY OF INTER-COLLEGIATE LEVEL SPRINTERS

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**Dr. M. John**, *Assistant Professor, Department of Physical Education, Annamalai University.*

### Abstract

The aim of this investigation was to determine the factors predominant to sprinting ability of university level sprinters. To attain this aim, the investigator selected 330 male inter-collegiate level sprinters as subjects. Random group design was used for this investigation, as it is most suitable. The age of the selected subjects was from eighteen to twenty five years. In this study one criterion (sprinting ability) and twenty determinant variables (anthropometric measurements, physical fitness components, physiological parameters and speed related parameters) were included. The relationship between criterion and determinant variables as well as inter-correlations among determinant variables was calculated by using Pearson product-moment correlation formula. The computation of multiple regressions was also used. Multiple regressions analysis was used to find out the predictor variable that has the highest correlation with the criterion variables and it is entered into the equation first. The rest of the variables are entered into the equation depending on the contribution of each predictor. To test the hypothesis 0.05 level of significance was fixed. The regression equation for the sprinting ability includes acceleration speed, stride frequency and anaerobic power.

**Keywords:** *Anthropometric, Physical, Physiological, Speed parameters and Sprinters*

### INTRODUCTION

100m sprint event is a spectacular event in track and field, it is a most dominant event compare with all other events. In the short distance running there is a purpose to overcome the gifted distance in the shortest possible time. The decisive factors of the sports performance structure are maximal running speed and the ability to keep it as longer as possible (speed endurance). Even in many different sports and events the maximal running speed participates either directly or not on the level of sports performance and sportsman's successfulness. That is why the development of speed abilities is very topical problem of the sports theory and practice. The great deal of genetic determination and limited possibilities of the speed abilities' development turn attention for the selection of talented youth and look for new, more effective means and methods of development.

Performance is the ability to achieve the high score in sprinting competitive event. Athletes are always in search of more speed. Running speed is an essential component of most major sports, and can be the determining factor in the outcome of a sporting event. It

is for this reason that athletes undertake training programs to improve their individual speeds. In order to gain a performance advantage, athletes are always in search of newer methods. While team court sports have been widely researched, few studies have been conducted comparing predominant characteristics of sprinters. Hence, this kind of analysis will allow the identification of the different components of performance and how they interact to influence performance in sprint.

Running speed is an essential component of most of the major sports. Often, it is the determining factor in the outcome of a sporting event. Thus, the ability to enhance running speed is of prime importance to coaches and athletes. Since the researcher is a sprinter, the investigator feels that there is a need for an analytical study in order to discriminate the dominant factors associated with the sprinting performance of inter-collegiate level sprinters. Moreover, limited number of researches had been done among inter-collegiate level sprinters, and also there is a lack of descriptive data on the sprinting ability of inter-collegiate level sprinters. This has motivated to take up the study to predict the factors predominant to the sprinting ability of inter-collegiate level sprinters.

## **METHODOLOGY**

### **Selection of Subjects**

To determine the association between the criterion and determinant variables, three hundred and thirty male inter-collegiate level sprinters from various arts and science colleges affiliated to Manonmaniam Sundaranar University, Tirunelveli and also from Madurai Kamaraj University, Madurai, Tamilnadu were chosen. Random group design was used, as it is most appropriate. The age of the subjects was from 18 to 25 years.

### **Selection of Variables**

**Criterion Variable:** The 100m sprinting performance of the selected sprinters were considered as criterion variable.

**Anthropometric Measurements:** The following anthropometric variables namely Height, arm length, leg length, thigh girth and calf girth were selected.

**Physical fitness components:** The physical fitness components such as maximum speed, explosive power, muscular strength, flexibility and dynamic balance were selected.

**Physiological parameters:** The physiological parameters such as resting heart rate, breath holding time, anaerobic power, forced vital capacity and  $VO_2$ max were selected.

**Speed Parameters:** Reaction time, acceleration speed, stride length, stride frequency and speed endurance were selected.

**Collection of Data**

The sprinting ability of the inter-collegiate level sprinters was assessed by conducting 100m race and the selected anthropometric measurements, physical fitness components and physiological parameters were measured through standard test and measurements.

**Statistical Techniques**

In this study one criterion (sprinting ability) and twenty determinant variables are included. The relationship between criterion and determinant variables as well as inter-correlations among determinant variables was calculated by using Pearson product-moment correlation formula. The computation of multiple regressions was also used. In multiple regressions, a criterion variable was predicted from a set of predictors. Multiple regressions analysis was used to find out the predictor variable that has the highest correlation with the criterion variables and it is entered into the equation first. The rest of the variables are entered into the equation depending on the contribution of each predictor. To test the hypothesis 0.05 level of significance was fixed.

**Result**

The descriptive statistics– range, minimum, maximum, mean and standard deviation of anthropometric, physical, physiological, speed parameters and playing ability of sprinters have been presented in table-I.

<b>Table – I: Descriptive Statistics Results of Chosen Anthropometric, Physical, Physiological, Speed Parameters and Sprinting Ability among Sprinters</b>						
	N	Range	Minimum	Maximum	Mean	SD
Height	330	15.00	154.00	169.00	1.6099E2	4.18311
Arm length	330	15.00	54.00	69.00	60.9939	4.18202
Leg length	330	10.00	69.00	79.00	75.0636	2.82287
Thigh girth	330	9.00	39.00	48.00	43.2333	2.72723
Calf girth	330	7.00	25.00	32.00	28.5030	1.56762
Speed	330	0.84	4.14	4.98	4.5257	0.14345
Power	330	50.00	2.00	52.00	45.2030	4.16141
Strength	330	10.00	59.00	69.00	64.9455	2.77035
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Balance	330	8.00	35.00	43.00	39.0636	1.96138
RHR	330	3.00	65.00	68.00	66.4758	1.19816
BHT	330	31.00	37.00	68.00	40.33	2.55
Anaerobic	330	26.00	260.00	286.00	2.7523E2	5.53767
FVC	330	0.54	3.05	3.59	3.3423	0.15795
Vo <sub>2</sub> max	330	0.31	2.64	2.95	2.8035	0.09017
Reaction	330	0.10	0.17	0.27	0.2239	0.02521
Acceleration	330	2.10	4.20	6.30	5.1763	0.51255
Stride length	330	0.22	1.63	1.85	1.7479	0.06054

Frequency	330	1.09	4.11	5.20	4.6064	0.29366
Endurance	330	2.13	17.12	19.25	18.0963	0.58069
Sprinting	330	2.20	11.10	13.30	12.0795	0.61959

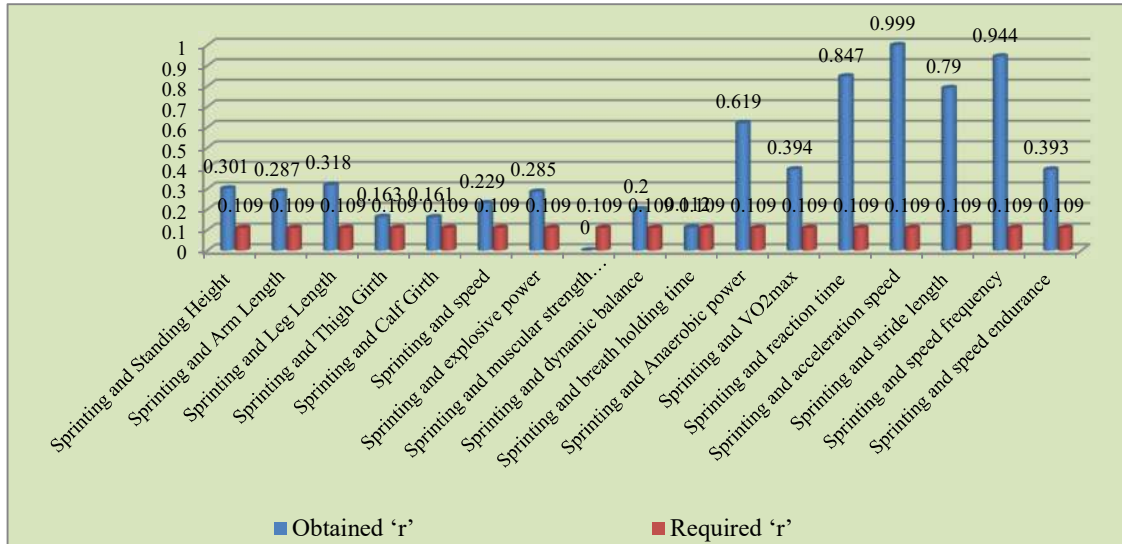
### Correlation Analysis

The inter-relationships between chosen anthropometric, physical, physiological and speed parameters with playing ability of sprinters were computed using Pearson Product Moment Correlation. It was evident from the Pearson Product Moment Correlation results that sprinting ability (SA) is significantly correlated with are height, arm length, leg length, thigh girth, explosive power, muscular strength, anaerobic power, VO<sub>2</sub>max, reaction time, stride frequency and speed endurance of sprinters.

The following anthropometrical variables; height (0.301), arm length (0.287), leg length (0.318) thigh girth (0.163), calf girth (0.161) were significantly correlated with the sprinting ability. High correlation also existed between sprinting ability versus selected physical fitness components namely speed (0.229), explosive power (0.285), muscular strength endurance (0.284) and dynamic balance (0.200). The chosen physiological components; breath holding time (0.112), VO<sub>2</sub>max (0.394) and anaerobic power (0.619) was significantly correlated with the sprinting ability. The selected speed parameters namely reaction time (0.847), acceleration speed (0.999), stride length (0.790), speed frequency (0.944), speed endurance (0.393) were highly correlated with the sprinting ability of the sprinters. As the obtained 'r' values was found at 0.05 level of confidence was higher than required table 'r' value 0.109.

The obtained and required 'r' values of selected anthropometric, physical, physiological, speed parameters with sprinting ability is displayed in table-I.

**Table – I: Correlation between Criterion and Determinant Variables**



**Step-Wise Multiple Regression Analysis**

Stepwise multiple regression was computed to explore the prediction of dominant factors of sprinting ability from the predictor variables of inter-collegiate sprinters.

The analysis of variance for the influence of predictor variables on sprinting ability among inter-collegiate sprinters is in table -II.

**Table II: Analysis of Variance for the Influence of Predictor Variables on Sprinting Ability Among Inter-collegiate Level Sprinters**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.877	1	8.877	15252.182	.000 <sup>b</sup>
	Residual	0.016	28	0.001		
	Total	8.894	29			
2	Regression	8.884	2	4.442	12062.074	.000 <sup>c</sup>
	Residual	0.010	27	.000		
	Total	8.894	29			
3	Regression	8.885	3	2.962	9077.734	.000 <sup>d</sup>
	Residual	0.008	26	.000		
	Total	8.894	29			

- a. Dependent Variable: sprint ability
- b. Predictors: (Constant), ACCSPEED
- c. Predictors: (Constant), ACCSPEED, STFRE
- d. Predictors: (Constant), ACCSPEED, STFRE, ANEROBIC

It was clear from the table-II that the obtained ‘F’ value 15252.18, 120602.07 and 9077.73 are significant (0.05 levels). Hence, all the independent variables are collectively influenced on the sprinting ability of sprinters.

As the F ratio is significant multiple regressions was computed. Multiple regression equation was computed only because the multiple correlations were sufficiently high to warrant prediction from it. Then, the correlation identified the independent variables to be included and their order in the regression equation. Multiple correlations were computed by step-wise argument method and the results were presented in Table – III.

**Table-III: Step-Wise Multiple Regression between Sprinting Ability and Independent Variables of Sprinters**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.999 <sup>a</sup>	0.998	0.998	0.02413
2	0.999 <sup>b</sup>	0.999	0.999	0.01919
3	1.000 <sup>c</sup>	0.999	0.999	0.01806

a. Predictors: (Constant), ACCSPEED

b. Predictors: (Constant), ACCSPEED, STFRE

c. Predictors: (Constant), ACCSPEED, STFRE, ANEROBIC

From table-III, it was found that the multiple correlations co-efficient for predictors, such as acceleration speed, stride frequency and anaerobic power was 1.000 which produce highest multiple correlations with sprinting ability. ‘R’ square values show that the percentage of contribution of predictors to the sprinting ability (Dependent variables) is in the following order.

1. About 99.8% of the variation in the sprinting ability was explained by the regression model with one predictor acceleration speed.

2. About 99.9% of the variation in the sprinting ability was explained by the regression model with two predictors, acceleration speed and stride frequency. An additional 0.001% of the variance in the sprinting ability was contributed by stride frequency.

3. About 99.9% of the variation in the sprinting ability was explained by the regression model with three predictors, acceleration speed, stride frequency and anaerobic power. An additional 0.001% of the variance in the sprinting ability was contributed by anaerobic power.

Multiple regression equation was computed and the obtained results are presented in Table – IV.



**Table-IV: Regression Analysis of Prediction Equation of Sprinters (Stepwise Method)**

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	6.911	.041		168.176	.000
ACCSPEED	1.017	.008	.999	123.500	.000
2 (Constant)	6.517	.100		64.915	.000
ACCSPEED	.945	.018	.929	51.112	.000
STFRE	.160	.039	.075	4.154	.000
3 (Constant)	7.189	.332		21.674	.000
ACCSPEED	.941	.017	.925	53.782	.000
STFRE	.146	.037	.069	3.968	.001
ANEROBIC	-.002	.001	-.016	-2.115	.044

a. Dependent Variable: sprinting ability

**Predictors in the Model 1:** (Constant), Acceleration Speed.

**Predictors in the Model 2:** (Constant), Acceleration Speed, stride frequency.

**Predictors in the Model 3:** (Constant), Acceleration Speed, stride frequency and anaerobic power.

From the Table-IV, the following regression equations were derived for sprinting ability of sprinters.

Regression Equation in obtained scores form = CR

Sprinting Ability = 6.911 + 0.941 (Acceleration Speed) + 0.146 (stride frequency) - 0.002 (anaerobic power)

The regression equation for the dominant factors of sprinting ability includes acceleration speed, stride frequency and anaerobic power. As the multiple correlations on dominant factors of sprinting ability with the combined effect of these predictor variables are highly significant, it is apparent that the obtained regression equation has a high predictive validity.

**Discussion**

According to the current study, the apparent importance of anthropometric variables in running speed. Stride length increases with body height, and strength and power with muscle development, thereby influencing the sprint performance (Papaiakovou, et al., 2009). The improvement in sprint performance is related to the maturation of the neural system and improved muscle/neural coordination, in addition to the increase in muscle mass (Malina, Bouchard & Bar-Or. 2004). Wong et al., (2009) found that taller players performed better in 10 m and 30 m sprint. In the growth spurt, the variations in maturation for the same chronological age have been shown be as

much as 2 or 3 years, or even more, and Malina et al., (2007) suggest that body mass and maturity account for 50% of variance in short sprint.

Barrera et al., (2022) analyze the relationship between sprint performance (time), and strength and power capabilities in football players and found that peak torque at higher velocities and vertical jump performance correlates significantly with linear sprint performance. Suarez-Arrones et al., (2020) suggested that despite the existence of substantial correlations between variables, straight linear sprinting, jumping performance, CODs and squat power were, for the most part, separate motor qualities, suggesting that all of them should be specifically assessed and trained. Loturco et al., (2019) identified that maximum running speed is a very complex physical capacity, which should be assessed and trained using several methods and training strategies.

Human physiology and physique combine to be the most influential determinants of improved sprint performance (Majumdar & Robergs (2011). Physiological profiling is used within team sports to assess both the demands of the sport and provide evidence of position specific requirements (Geithner et al., 2006). For all athletes involved in high professional competitive sports the body is required to perform at optimum capacity in terms of biomechanics and physiology (Zaccagni, 2012).

Numerous investigators have attempted to isolate predictive factors for the selection of track and field athletes (Foreman, 1989; Henson et al., 1989a). Alabin et al., (1980) identified the following factors as predictors of track and field talent: height, weight, speed, stride frequency and stride length, reaction time, strength, power, endurance, coordination, psychological approaches, intellectual level, and biological growth rate. Foreman (1989) outlined some of the characteristics related to successful performance in terms of relative importance in various events. In the area of sprints and hurdles, natural speed, power, stride cadence, strength, movement time, and low percent fat were considered important.

### **Conclusion**

The sprinting ability was significantly correlated with height, arm length, leg length, thigh girth, calf girth, speed, explosive power, muscular strength endurance, dynamic balance, breath holding time, VO<sub>2</sub>max and anaerobic power, reaction time, stride frequency and speed endurance of sprinters. The predictor variables namely acceleration speed, stride frequency and anaerobic power can be used to predict the sprinting ability of inter-collegiate level sprinters.

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# AEGAEUM JOURNAL

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## Certificate of Publication

This is to certify that the paper entitled

**“PREDICTION OF THE FACTORS PREDOMINANT TO SPRINTING ABILITY  
OF INTER-COLLEGIATE LEVEL SPRINTERS”**

Authored by:

**V. Viju, Ph.d -Scholar**

From

**Annamalai University.**

Has been published in

**AEGAEUM JOURNAL, VOLUME X, ISSUE XI, NOVEMBER - 2022**



*S. Wimberger*  
S. Wimberger  
Editor-In-Chief  
AEGAEUM JOURNAL



From

Dr. R. Rooban Raja Sekhar

Head of the Department

Department of English

Nanjil Catholic College of Arts & Science  
Kaliyakkavilai

To

The Principal

Nanjil Catholic College of Arts & Science

Kaliyakkavilai

Respected Sir,

Sub: Seeking permission to send II M.A English  
Students to Kerala University Library, Trivandrum

I am writing to seek your permission to  
send II M.A English literature students to Kerala  
University Library, Trivandrum to refer books and  
Journals on 31/10/2022, Monday as a part of their  
research work. So I request you to kindly provide  
bonafide certificate for the students and OD for the  
accompanying staff (M.S. Subi)

Thanking you

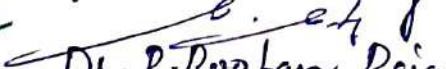
Kaliyakkavilai

29/10/2022



A.   
PRINCIPAL  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153

Yours Faithfully

  
Dr. R. Rooban Raja Sekhar



# Nanjil Catholic College of Arts & Science

NEDUMCODE, KALIYAKKAVILAI - 629 153,  
K.K.DISTRICT, TAMIL NADU

(Accredited with 'B' by NAAC)  
(Approved by UGC under section 2(f) & 12(B) status)

Phone : 04651-244788, Mobile : 8903013368, E-mail : nanjilccas@gmail.com, Website : www.nccas.edu.in

## BONAFIDE CERTIFICATE

This is to certify that the Department of English, Nanjil Catholic College of Arts and Science, Kaliyakkavilai is taking 26 students (II M.A. English) with 1 staff member to visit Kerala University Library, Thiruvananthapuram on 31<sup>st</sup> October 2022. Herewith the name of the students list is enclosed.

Kaliyakkavilai  
29.10.2022



  
Principal  
PRINCIPAL  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153.

1/10/22

Name of the Staff

Mrs. M S Subi

Name of the Students

**II M.A. English**

1. Abisha R J
2. Angel Jefferin F N
3. Ashika G M
4. Ashika P S
5. Susmitha R V
6. Anisha T
7. Subi S
8. Bretti Star S
9. Benisha M S
10. Jinisha R
11. Keerthana Mol C P
12. Saffrin S
13. Christy Mol C T
14. Praveena P
15. Vidya Chanfra R G
16. Geedhu R
17. Jesty Felsi J
18. Jerfin J
19. Thanesh T S
20. Manju C
21. Prathysha F S
22. Angel Benisha S
23. Saranya S
24. Stephiya A
25. Vinisha G
26. Chinchu M



**PRINCIPAL**

Nanjil Catholic College of Arts & Science  
Kaliyakkavilal - 629 153.

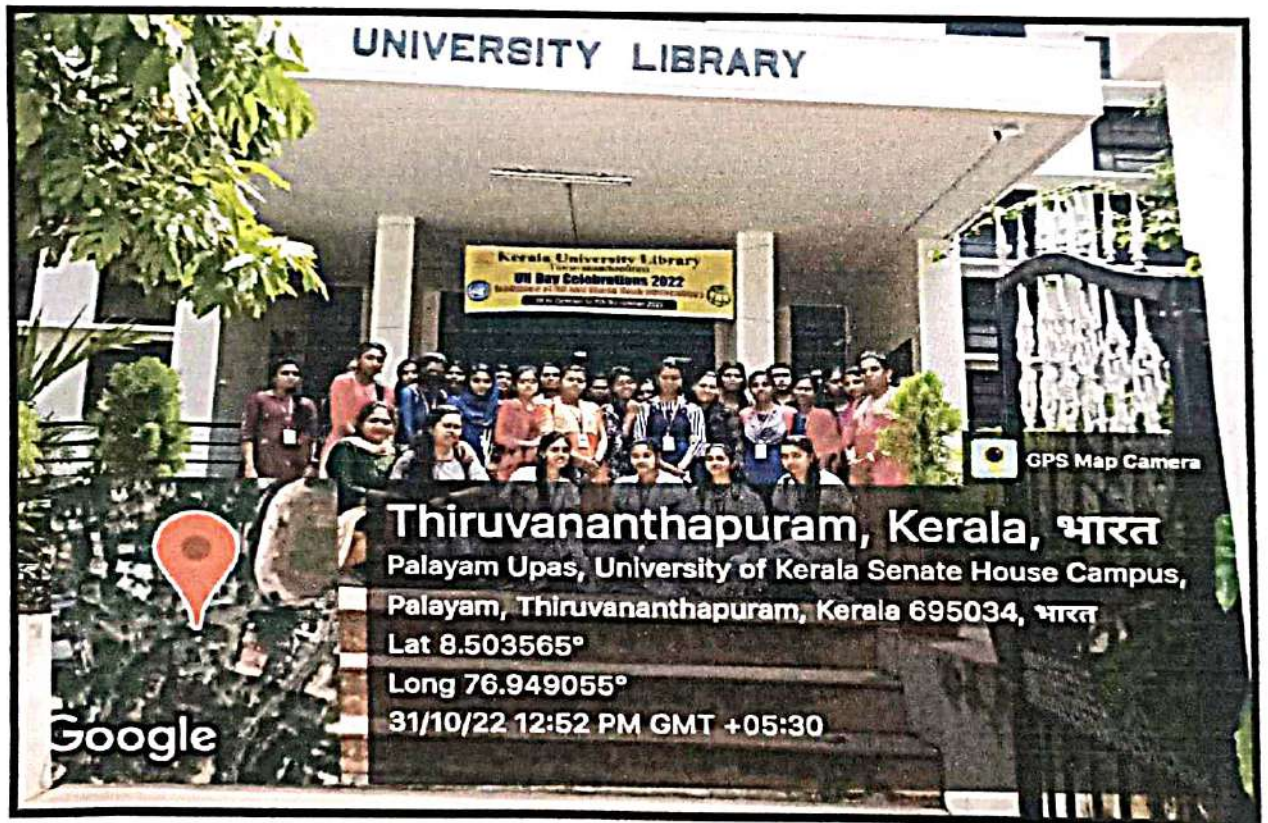


**NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE**  
Kaliyakkavilai

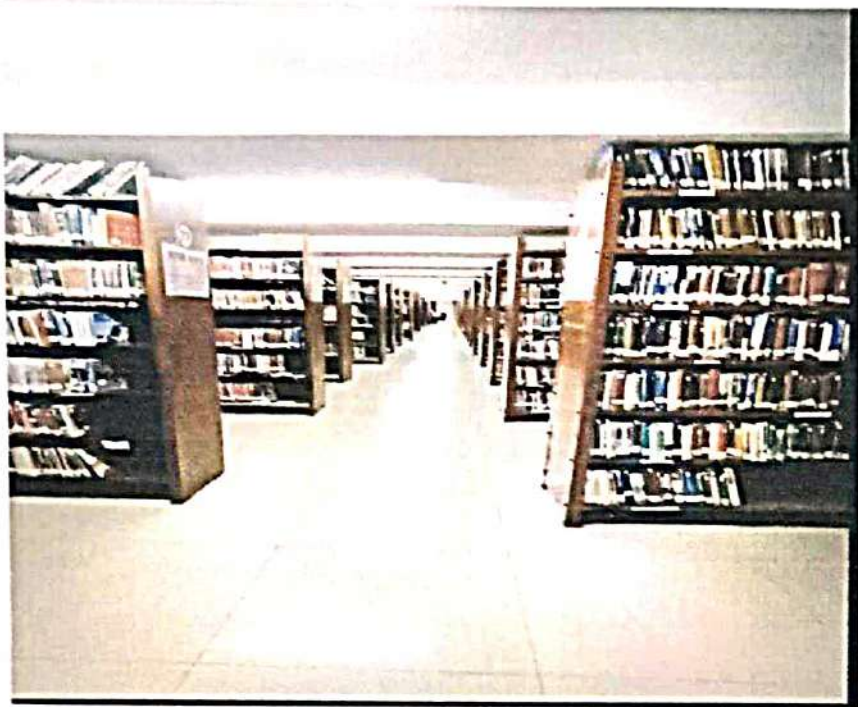
**DEPARTMENT OF ENGLISH**

**LIBRARY VISIT REPORT FOR THE ACADEMIC YEAR 2022-2023**

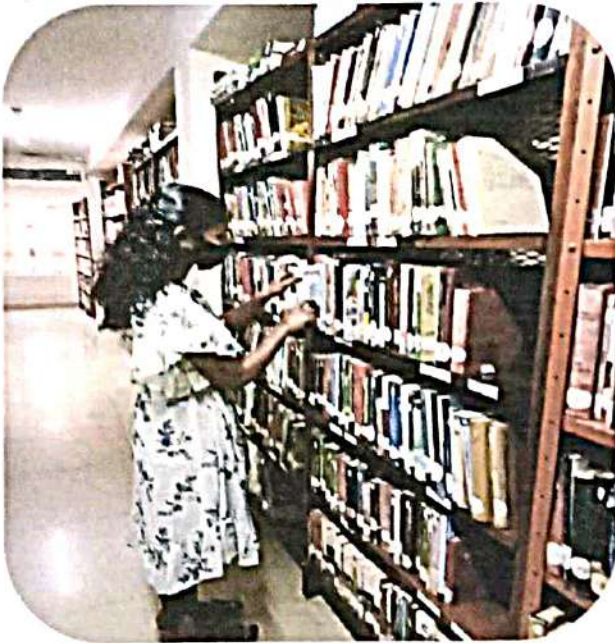
A library visit was organized by the Department of English on 31st October 2022. For the Post-Graduate students of English. The journey started with a prayer. The group of 26 students, accompanied by one staff left Kaliyakkavilai at 7.00 AM and reached the Kerala University library at 8:15 AM. The Kerala university library was established in 1942. It is the oldest and biggest university library in Kerala and is situated adjacent to the university senate Hall campus in the Thiruvananthapuram city.



It offers digital information services just such as UGC Info net. The special collections also included women's studies, government publication, general biographies, journals and rare books.




It had a huge collection of books, journals and theses located in three floors with each floor spanning over long sections of bookshelves. The whole day from 9.00 AM in the morning to 4:00 PM in the evening was spent in the library with the students eagerly reading the books available. Decades old books were also available to read and refer the times spent in the library was effectively used by the students.



They took many notes on topics related to their projects from the theses and books. The day ended with discussions on the work done by every student. It was very helpful to develop researching ability of the students.



  
Head  
Department of English  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153, Tamil Nadu

## **The Visit to an Orphanage**

The visit to an Orphanage is a life-changing experience as it is filled with emotions and sentiments. The staff members, Mrs. Merlin Mahil and Mrs. Sajitha Sajan, Assistant Professors of Department of English, Nanjil Catholic College of Arts and Science, Kaliyakkavilai were lucky to get an opportunity to visit the Orphanage in YMCA, Muzhucode on July 27, 2023.

There were around 20 children with 2 care takers and a woman in charge. The house was in good condition. When the professors visited the orphanage, the children had gone to the school. The age group of the children was ranging from 5 years to 14 years. The professors had brought snacks for the children. They enquired about the facilities available and the children who had left the orphanage.



  
Head  
Department of English  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153, Tamil Nadu.





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Date: 01-05-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Deep Learning based Workers Safety Helmet Wearing Detection on Construction Sites using Multi-Scale Features** is a bonafide record of the work done at our company by **Abijith K. A (Reg.No 20213102506201)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution





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This is to certify that the project entitled **Stress Detection in IT Professional by Image Processing and Deep Learning** is a bonafide record of the work done at our company by **A. Adchaya (Reg.No 20213102506202)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





April 29<sup>th</sup>, 2023

## TO WHOMSOEVER IT MAY CONCERN

**Aiswarya M.S (Reg No: 20213102506203)** Who is pursuing studies for the award of Final year Student of "**Nanjil Catholic College Of Arts and Science , Kaliyakkavilai**" has completed the Project work on "**Predicting poverty level from satellite imagery**" in **WEBKING TECHNOLOGY, Marthandam** for the Academic year **2022-2023**.

The above student has successfully completed the Project Work. She is sincere and hard worker while her project period.



Yours Sincerely,

For **Webking Technology,**

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This is to certify that the project entitled **Electricity Theft Detection in Smart Grids Based on Deep Neural Network** is a bonafide record of the work done at our company by **Angelin Bomy K (Reg.No 20213102506204)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

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Project Manager

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29.04.2023

Date: .....

## CERTIFICATE

### TO WHOM SO EVER IT MAY CONCERN

This is to certify that, Ms.ARSHA MARY.B (Reg. No: 20213102506205), student studying M.Sc., (Computer Science) in Nanjil Catholic College of Arts & Science, Kaliyakkavilai, have successfully completed her Project entitled "SECURE IoT ASSISTANT BASED SYSTEM FOR ALZHEIMER'S DISEASE" with us from 02.01.2023 to 29.04.2023. During the period of her project her performance was good.

We wish her all best for her bright future.

For HiTech Solutions

*P. S. Venkatesh*





April 29<sup>th</sup>, 2023

## TO WHOMSOEVER IT MAY CONCERN

**Ashmi R k (Reg No: 20213102506206)** Who is pursuing studies for the award of Final year Student of **"Nanjil Catholic College Of Arts and Science , Kaliyakkavilai"** has completed the Project work on **"Cotton disease detection tensor flow using machine learning technique"** in **WEBKING TECHNOLOGY, Marthandam** for the Academic year **2022-2023**.

The above student has successfully completed the Project Work. She is sincere and hard worker while her project period.

  
Yours Sincerely,  
For **Webking Technology,**



April 29<sup>th</sup>, 2023

## TO WHOMSOEVER IT MAY CONCERN

**Athira B.A (Reg No: 20213102506207)** Who is pursuing studies for the award of Final year Student of **"Nanjil Catholic College Of Arts and Science , Kaliyakkavilai"** has completed the Project work on **"Fake product identification system using Blockchain Technology"** in **WEBKING TECHNOLOGY, Marthandam** for the Academic year **2022-2023**.

The above student has successfully completed the Project Work. She is sincere and hard worker while her project period.



Yours Sincerely,  
For **WebKing Technology,**

April 29<sup>th</sup>, 2023

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**Benita S.R (Reg No: 20213102506208)** Who is pursuing studies for the award of Final year Student of "**Nanjil Catholic College Of Arts and Science , Kaliyakkavilai**" has completed the Project work on "**Brain Tumor Detection using Transfer Learning with Dimensionality Reduction Method**" in **WEBKING TECHNOLOGY, Marthandam** for the Academic year **2022-2023**.

The above student has successfully completed the Project Work. She is sincere and hard worker while her project period.



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This is to certify that the project entitled **A New Improved multi Input Color U-net model for Skin Lesion Sematic Segmentation** is a bonafide record of the work done at our company by **Berjin Jose J (Reg.No 20213102506209)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

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Date: 01-05-2023

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This is to certify that the project entitled **Lung Cancer Detection using Machine Learning** is a bonafide record of the work done at our company by **Blessen Jose J.S** (Reg.No 20213102506210), student of Department of Computer Science, Nanjil Catholic College of Arts and Science, Kaliyakkavilai, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of 02 January 2023 to 29 April 2023. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





April 29<sup>th</sup>, 2023

**TO WHOMSOEVER IT MAY CONCERN**

**Lintu A (Reg No: 20213102506211)** Who is pursuing studies for the award of Final year Student of **"Nanjil Catholic College Of Arts and Science , Kaliyakkavilai"** has completed the Project work on **"A secure electronic medical record based on Blockchain technology"** in **WEBKING TECHNOLOGY, Marthandam** for the Academic year **2022-2023**.

The above student has successfully completed the Project Work. She is sincere and hard worker while her project period.



Yours Sincerely,  
For **Webking Technology,**





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftware.com.in](http://www.gladesoftware.com.in)

**Date: 01-05-2023**

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Random Positioned License Plate Recognition Using Hybrid Board Learning system and Convolutional Networks** is a bonafide record of the work done at our company by **Reshma R (Reg.No 20213102506212)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftwaresolution.in](http://www.gladesoftwaresolution.in)

Date: 01-05-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Reflection-Decomposition based Transmission map estimation for Underwater Image Restoration** is a bonafide record of the work done at our company by **Shala R.L (Reg.No 20213102506213)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftwaresolution.in](http://www.gladesoftwaresolution.in)

Date: 01-05-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Prediction of Heart Disease using Machine Learning** is a bonafide record of the work done at our company by **Sherbin S.R** (Reg.No 20213102506214), student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftwaresolution.in](http://www.gladesoftwaresolution.in)

Date: 29-04-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **A Novel Graphical Randomized Authentication technique for Smart Devices** is a bonafide record of the work done at our company by **Sherla S (Reg.No 20213102506215)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftwaresolution.in](http://www.gladesoftwaresolution.in)

Date: 01-05-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Blood Group Detection Using Image Processing** is a bonafide record of the work done at our company by **Shyni S (Reg.No 20213102506216)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.





# Glade Software Solution

Near Standard Auditorium, North Street, Marthandam-629 165

Tel: +91 4651-295618

Website: [www.gladesoftwaresolution.in](http://www.gladesoftwaresolution.in)

Date: 01-05-2023

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project entitled **Diabetic Retinopathy Detection Using Machine Learning** is a bonafide record of the work done at our company by **Subha S (Reg.No 20213102506217)**, student of Department of Computer Science, **Nanjil Catholic College of Arts and Science, Kaliyakkavilai**, in partial fulfillment of the requirements for the award of the M.Sc Computer Science, during the period of **02 January 2023 to 29 April 2023**. The matter contained in the project work has not been submitted for the award of any other degree.

We wish you all the best for your future career.

Regards,

Mr. M. Suresh Babu M.B.A., B.E

Project Manager

Glade Software Solution

Marthandam.



GSTIN 33ANPPJ5635E1ZO

Mob : 9443040571

# R.K. METALS

Aluminium, Steel, Copper & Brass Merchant

Thazhivilai, Kappukadu P.O.

Date 4-4-2023

Mr. ....

---

## CERTIFICATE

This is to certify that **Mr. Abishek H**, Register No. 20203101201201, BBA student of **Najil Catholic College of Arts and Science, Kaliyakkavilai**, under **Manonmaniam Sundaranar Univertisty** has successfully completed his project titled "**Employee Retention at R K METALS in Kappukadu**" during the period from **08-12-2022 to 07-01-2023**.

During our association with him, we have found him to be enthusiastic, sincere and hard working.

Kappukadu

Yours Sincerely,



For, **R.K. Metals**



1<sup>st</sup> May, 2023

### CERTIFICATE

This is to certify that Mr. Ali Arafath S, Register No. 20203101201203, BBA student of Nanjil Catholic College of Arts and Science, Kaliyikkavilai, under Manonmaniam Sunderanar University has successfully completed his main project titled "A study on Employee Motivation at Luke Export in Padanthalumoodu" during the period from 26/12/2022 to 18/01/2023.

During our association with him, we have found him to be enthusiastic, sincere and hardworking.

For LUKE Export

Manager





# CAPITAL POLYMERS

Manufacturers of Plastic Water Storage Tanks

An ISO 9001-2015 Company

GST: 32BHCP57440A1ZR, Factory: Kandala P.O. Koovalassery, Kattakada, Thiruvananthapuram-695 512

Phone: 0471-2298010, Email: capitalpolymers1998@gmail.com, Web: www.capitalpolymer.com

Date: 03/05/2023

This is to certify **MR. ANUJITH K A** (Reg.No.20203101201204) perusing BBA at "NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE, KALIYAKKAVILAI, K.K. District". He has done the project work under the topic of "**A STUDY ON CUSTOMERS PREFERENCE IN CAPITAL POLYMERS AT KANDALA**". During his period with us we found him excellent in his performance and having good conduct and character.

We wish him all success in her future endeavour.

Thanking You

For CAPITAL POLYMERS

*James*  
MANAGER





# Lofty Optical Industries

An ISO 9001 : 2015 Certified Company

E-mail : loftyindia@gmail.com

Website : www.loftyindia.com

Date: 02/05/2023

## TOWHOMSOEVER IT MAY CONCERN

This is to certify that **MR. BRITTO A** (Reg.No.20203101201206) Perusing BBA at "NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE, KALIYAKKAVILAI, K.K. District. He has done the project work under the topic of "A Study on AN ASSESSMENT OF PERFORMANCE APPRAISAL ON PRODUCTIVITY" at "LOFTY OPTICAL INDUSTRIES PUTHUKADAI" from 28<sup>th</sup> DECEMBER 2022 TO 7<sup>th</sup> JANUARY 2023. He is very excellence, her contact and character during this period was found good.

*We wish him all success in her future endeavor.*

Thanking You

LOFTY OPTICAL INDUSTRIES

Authorized Signature



Date: 09.01.2023

## CERTIFICATE


This is to certify that Mr. Geo R Riza ( Reg. No. 20203101201207 ) Third Year B.B.A. student of Nanjil Catholic College of Arts And Science, Kaliyakkavilai has undergone **Industrial Project** under the topic " **A Study on Consumer Buying Behavior**" for the period from 08.12.2022 to 07.01.2023 at our various dealer's point. He has been regular in his attendance during this period.

He has gained Good Knowledge in all aspects of the assigned topic during his Industrial Project.

WE WISH HER ALL SUCCESS.

For BG Crop Science & Technologies (P) Ltd.,



  
Winny Irwin Jose  
(Chief Executive Officer)



# CERTIFICATE OF APPRECIATION

This is to certify that Mr./Ms. *Lejitha Dhas S*  
from *St. Joseph's Catholic College of Arts & Science*  
has been engaged with us from *26/11/2022* to *06/01/2023*  
as for *doing the academic Project*  
under *Finance & Accounts* Department.

We appreciate his/her hard work and wish success in his/her academic career and future endeavours.

For Muralya Dairy



# Sneha Hospital

Kannumamoodu

E-mail: snehahospital@gmail.com

Date: 01/05/2023

## TRAINING CERTIFICATE

This is to certify that Mithra M.P (Reg.no: 20203101201210) Third year BBA Student of Nanjil Catholic College of Arts and Science has successfully completed her magor project in our organization,. The duration of the time is

08/12/2022 - 07/01/2023

Thank you

  
Sowmya S

H R Manager



SH/HR/IL/2023/379

03<sup>rd</sup> May, 2023

**TO WHOM SO EVER IT MAY CONCERN**

This is to certify that **Mr. Mohammad Adnan S A** (Register No - **20203101201211**) a **BBA** student of **Nanjil Catholic College of Arts And Science, Kaliyakkavilai** has successfully completed his curriculum required project at Saraswathy Hospital, Parassala from 3<sup>rd</sup> January, 2023 to 12<sup>th</sup> January, 2023.

We wish all success for his future endeavours

For **Sarawathy Hospital**

  
04/05/2023



**Praveen P**

**Chief Executive Officer**



SH/HR/IL/2023/378

03<sup>rd</sup> May, 2023

**TO WHOM SO EVER IT MAY CONCERN**

This is to certify that **Mr.NITHEESH Y (Register No - 20203101201212)**, a BBA student of **Nanjil Catholic College of Arts And Science, Kaliyakkavilai** has successfully completed his curriculum required project at Saraswathy Hospital Parassala from 03<sup>rd</sup> January, 2023 to 12<sup>th</sup> January,2023.

We wish all success for his future endeavours.

For **Sarawathy Hospital**

  
04/05/2023



**Praveen P**

**Chief Executive Officer**

MURALYA

DAIRY

The real milk people!

# CERTIFICATE OF APPRECIATION

This is to certify that ~~Mr~~/Ms *Priya Bharshini C. G*  
from *Nanjil Catholic College of Arts & Science*  
has been engaged with us from *26/12/2022* to *06/01/2023*  
as for *doing the academic Project*  
under *Human Resource* Department

We appreciate his/her hard work and wish success in his/her academic  
career and future endeavours.

For Muralya Dairy





# AYPOLS POLYMERS PRIVATE LIMITED

Mfrs. & Suppliers : All Kinds of Unsaturated Polyester Resins  
And Fibre Glass Raw Materials



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Coimbatore - 641 044 Ph : 0422 4387801 / T.Fax : 2521801  
e-mail : aypolsipol@gmail.com, sales@aypolspolymers.com

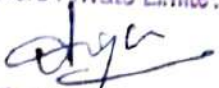
CIN : U24304T22017PTC029011 GSTIN : 33AAPCA6502P1ZC State : Tamil Nadu - 33

## TO WHOMSOEVER IT MAY CONCERN

This is to certify that Mr. RONALD . W (Reg No: 20203101201214) Student of III BBA in **Nanjil Catholic College of Arts and Science , Kallyakkavilai**. Has successfully completed his organizational study at **Aypols Polymers Private Limited, Coimbatore – 44** from 08-12-2022 to 07-01-2023 as part of his curriculum.

We wish all success for his future endeavors.

For Aypols Polymers Private Limited

  
Authorised Signatory



# Lofty Optical Industries

An ISO 9001 : 2015 Certified Company

E-mail : [loftyindia@gmail.com](mailto:loftyindia@gmail.com)

Website : [www.loftyindia.com](http://www.loftyindia.com)

Date: 02/05/2023

## TOWHOMSOEVER IT MAY CONCERN

This is to certify that **MR. SAI SABARISH A S** (Reg.No.20203101201215) Perusing BBA at "NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE, KALIYAKKAVILAI, K.K. District. He has done the project work under the topic of "*A Study on THE EFFECTIVENESS OF SALES PROMOTIONAL SCHEME*" at "LOFTY OPTICAL INDUSTRIES PUTHUKADAI" from 28<sup>th</sup> DECEMBER 2022 TO 7<sup>th</sup> JANUARY 2023. He is very excellence, her contact and character during this period was found good.

*We wish him all success in her future endeavor.*

Thanking You

LOFTY OPTICAL INDUSTRIES

Authorized Signature



Date: 07/02/2023

**CERTIFICATE**

His is to certify that Mr.SARATH. B. J (Reg No:20203101201216) doing Bachelor of Business Administration in NANJIL CATHOLIC COLLEGE OF ARTS & SCIENCE KALIYAKKAVILAI has done project under the title "INDUSTRIAL PROJECT", KS CASHEW FACTORY RAMAVARMANCHIRAI" Period on 08-12-2022 to 07-01-2023. During the period his attitud Were found good . We wish his all success in his future endeavor.

Thank You

*For K.S.Cashews Factory*  
  
Proprietrix



## **Teejay Prabha Milk and Nutriment Private Limited**

Prabha Diary Garden, Alancholai P.O, Kanniyakumari District - 629101, Tamil Nadu , Ph: 94435 95390

### **To Whomsoever it may concern**

This is to certify that **Miss. SHAHINA S (Registration Number 20203101201217)** is a **BBA student at Nanjil Catholic College Of Arts & Science, Kaliyakkavilai.** has successfully completed her curriculum-required Project at **Teejay Prabha Milk & Nutriment Pvt. Ltd.** from **December 8<sup>th</sup> 2022 to January 7<sup>th</sup> 2023.**

We wish all success for her future endeavours.

**For Teejay Prabha Milk & Nutriment Private Limited**

Authorised Signatory





1<sup>st</sup> May, 2023

### CERTIFICATE

This is to certify that Mr. Shubin C, Register No. 20203101201218, BBA student of Nanjil Catholic College of Arts and Science, Kaliyikkavilai, under Manonmaniam Sunderanar University has successfully completed his main project titled "A study on Supply Chain Problems faced by Luke Export, Padanthalumoodu" during the period from 12/12/2022 to 06/01/2023.

During our association with him, we have found him to be enthusiastic, sincere and hardworking.

For LUKE Export

Manager



# **MATHA PVC AND POLYTHENE PIPE COMPANY**

GST Number : 33EQJPS5927K1Z7

## **To whom so ever it may concern**

**This is to certify that MS.Shinu S (Reg No : 2020 310120 1219)  
student of BBA in Nanjil Catholic College of Arts & Science  
Kaliyakkavilai has successfully conducted Industrial project titled " A  
STUDY ON JOB SATISFACTION IN MATHA PVC & POLYTHENE PIPE  
COMPANY, KURANKADI, SURULACODE".**

**During our association with him, we found him to be enthusiastic,  
hard working and sincere.**

**For Matha Pvc and Polythene Pipe Company**

  
**Authorised signatory**



## **Teejay Prabha Milk and Nutriment Private Limited**

Prabha Dairy Garden, Alancholai P.O, Kanniyakumari District - 629101, Tamil Nadu , Ph: 94435 95390

### **To Whomsoever it may concern**

This is to certify that **Miss. THRESE RESHKA F** (Registration Number **20203101201220**) is a **BBA** student at **Nanjil Catholic College Of Arts & Science, Kaliyakkavilai**. has successfully completed her curriculum-required Project at **Teejay Prabha Milk & Nutriment Pvt. Ltd.** from **December 8<sup>th</sup> 2022 to January 7<sup>th</sup> 2023**.

We wish all success for her future endeavours.

**For Teejay Prabha Milk & Nutriment Private Limited**

Authorised Signatory



# MIGHTY PVC COMPANY

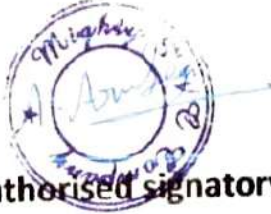
GST Number : 33CEIPP9306J1Z7

To whom so ever it may concern

This is to certify that MS. Vijisha B.O (Reg No : 2020 310120 1221) student of BBA in Nanjil Catholic College of Arts & Science Kaliyakkavilai has successfully conducted Industrial project titled "A STUDY ON CUSTOMER SATISFACTION IN MIGHTY PVC COMPANY, KANJIKUZHI, SURULACODE".

During our association with him, we found him to be enthusiastic, hard working and sincere.

For Mighty Pvc Company



Authorised signatory

Door No. 4/511B, Surulacode, Kalkulam Thesil, Kanyakumari Dist., Tamil Nadu - 629164  
Email : mightypipes.in@gmail.com, mightyindustries.ad@gmail.com, Website : www.m3p.in., Mob No. : 9995702095, Office 740273106



# CAPITAL POLYMERS

Manufacturers of Plastic Water Storage Tanks

An ISO 9001:2015 Company

GST: 32BHCPST440A1ZR, Factory: Kandala P.O, Koovalassery, Kattakada, Thiruvananthapuram-695 512  
Phone: 0471-2298010, Email: capitalpolymers1998@gmail.com, Web: www.capitalpolymer.com

Date: 3/05/2023

This is to certify that **MR.VISHNU M.S** (Reg.No.20203101201222) Pursuing BBA at "NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE, KALIYAKKAVILAI, K.K. DISTRICT". He has done the project work under the topic of "**A STUDY ON EMPLOYEE WELFARE FACILITY AT CAPITAL POLYMERS, KANDALA**". During his period with us we found him excellent in his performance and having good conduct and character.

We wish him all success in his future endeavour,

Thanking You

For CAPITAL POLYMERS

  
MANAGER





# KERALA STATE ELECTRONICS DEVELOPMENT CORPORATION LTD.

(A Government of Kerala Undertaking)



ISO 9001:2015 CERTIFIED

**Keltron Communication Complex** Telephone : 0471-2598948 (5 lines)  
Monvila, Kulathoor P. O. Fax : 0471-2598984  
Thiruvananthapuram-695 583 KERALA, INDIA E-mail : cgmccc@keltron.org  
CIN: U74999KL1972SGC002450

KCC/HRD/PW/2023/302

17/06/2023

## CERTIFICATE

This is to certify that **Mr. Abin Raj R**, MSW (HR) 4<sup>th</sup> semester Student of Nanjil Catholic College of Arts and Science, Tamil Nadu has successfully completed his Industrial training during the period from 2<sup>nd</sup> June 2023 to 17<sup>th</sup> June 2023 in our organization as a part of his academic curriculum under our guidance.



MINI D L  
SR OFFICER (HR&ADMN)



ISO 9001 : 2015



**INSTITUTE OF MENTAL HEALTH  
(MADRAS MEDICAL COLLEGE & RESEARCH INSTITUTE)  
KILPAUK, CHENNAI – 600 010, INDIA.  
PHONE: +91 – 44 – 26421918  
EMAIL: [directorimh2013@gmail.com](mailto:directorimh2013@gmail.com)**

**Date: 14/06/2023**

**TO WHOMSOEVER IT MAY CONCERN**

This is to certify that., M. ABISHA doing MSW (Master of social work), 2<sup>nd</sup> year in Nanjil Catholic College of Arts and Science Kaliyakkavilai, has successfully completed her Internship under my Guidance at **Institute of Mental Health, Department of Social Work, in psychiatry setting, Chennai from 29th of May 2023 to 17th of June 2023.**

During the placement trainee was gaining exposure in case study, group work discharge Counselling, home visit, facilitated mentally challenged patients to get disability certificates in the OP department and got orientation in psychology department.

Trainee actively participated in all the activities and showed great interest in Psychiatry setting.

**SOCIAL WELFARE OFFICER**

**SOCIAL WELFARE OFFICER  
INSTITUTE OF MENTAL HEALTH,  
KILPAUK, CHENNAI- 600 010.**

**DIRECTOR**

Date: 24-06-2023

## INTERNSHIP COMPLETION CERTIFICATE

This is to certify that Mr. AJAI R, Reg No: 20213102108205 student of NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE, KALIYAKKAVILAI, KANYAKUMARI DISTRICT Department of MSW(HR) has successfully completed his HR INTERNSHIP from 24-05-2023 to 24-06-2023 in our organization.

During the tenure of training, we found his sincere, attentive and good behaviour.

For Infogro Technology  
  
Authorised signature



## CERTIFICATE


This is to certify that **Ms. Ajitha.U** 2<sup>nd</sup> year 4<sup>th</sup> semester MSW (MEDICAL and PSYCHIATRY) Studying in **Nanjil Catholic College of arts and science**, Kaliyikkavilai, Tamilnadu had been an internee from **24<sup>th</sup> May 2023 to 20<sup>th</sup> June 2023** for the duration of 20 days.

She was trained under a Psychiatrist and a clinical psychologist. And was exposed to different Neuro – Psychiatric illness and de-addiction cases.

She was trained in counseling techniques, Psychometric analysis methods & to apply Psychological scales and Questionnaires.

**She was found obedient and punctual during the period of Training.**

  
Psychiatrist  
**Dr. SHASHANK H.V.**  
M.S.B.M.D.  
Neuro Psychiatrist  
**AAshritha Hospital**  
#5/A, hebbal Industrial Housing Area  
Hebbal, Mysuru 570 016  
KMC No 92315

  
Director  
**Dr. NAVEEN KUMAR A.**  
B.P.T, M.I.A.P., D.C.C., F.I.N.R., F.I.O.R., F.I.S.P  
First Contact Rehab Specialist  
**DIRECTOR**  
**AAshritha Hospital**  
#5/A, hebbal Industrial Housing Area  
Hebbal, Mysuru - 570 016  
I.A.P Reg. No L2516F

# 5/A, Hebbal Industrial Housing Area, Hebbal, Mysore-570 016

E-mail : [aashrithahospitalmysore@gmail.com](mailto:aashrithahospitalmysore@gmail.com)

Web : [www.aashrithahospitals.in](http://www.aashrithahospitals.in)

Ph : 0821-2581766 / 9342497979



# KARUNASAI

## DE-ADDICTION & MENTAL HEALTH RESEARCH INSTITUTE

Vellanad, Thiruvananthapuram-695543, Kerala  
Wed: [www.karunasai.com](http://www.karunasai.com), Mail: [karunasai.tvpm@gmail.com](mailto:karunasai.tvpm@gmail.com)  
Tel: +91 472 2883856, +91 9995853075

Date 15/06/2023

### CERTIFICATE

This is to certify that **Akash M J** a bonafide student of **Nanjil Catholic College of Arts & Science** pursuing his 2<sup>nd</sup> year MSW (Medical and Psychiatry) had successfully completed internship training programme at Karunasai De-addiction & Mental Health Research Institute from 23/05/2023 to 15/06/2023 (15 days).

During the tenure of internship, his conduct was satisfactory and he actively participated in all the activities of **Karunasai De-Addiction & Mental Health Research Institute**. We wish him all the best for his future endeavors.

**Training Supervisor**

**Project coordinator**





**KERALA STATE ELECTRONICS  
DEVELOPMENT CORPORATION LTD.**

(A Government of Kerala Undertaking)



**Keltron Communication Complex** Telephone : 0471-2598948 (5 lines)  
Monvila, Kulathoor P. O.  
Thiruvananthapuram-695 583 Fax : 0471-2598984  
KERALA, INDIA  
CIN: U74999KL1972SGC002450 E-mail : cgmkcc@keltron.org

KCC/HRD/PW/2023/304

17/06/2023

**CERTIFICATE**

This is to certify that **Ms. Angelin Arthi**, MSW (HR) 4<sup>th</sup> semester Student of Nanjil Catholic College of Arts and Science, Tamil Nadu has successfully completed her Industrial training during the period from 2<sup>nd</sup> June 2023 to 17<sup>th</sup> June 2023 in our organization as a part of her academic curriculum under our guidance.



**MINI D L  
SR OFFICER (HR&ADMN)**



ISO 9001 : 2015



കുളത്തൂർ ഗ്രാമപഞ്ചായത്ത്  
ബഡ്സ് റിഹാബിലിറ്റേഷൻ സെന്റർ

മേലേ വെട്ടുകാട്, പ്ലാന്തോട്ടം, കുളത്തൂർ ഉച്ചകടവു പി.ഒ

നമ്പർ. TVM/TC/778/2021

തീയതി.....19/06/2023

Certificate

This is to certify that  
Mrs. ANJANA.S.KUMAR, 25 years 4<sup>th</sup>  
Semester M.S.W Student of Nanyil  
Catholic college of Arts and Science  
Kaliyikkavilai, Tamil Nadu District has  
Successfully completed "25 day" of Block  
Placement in our Buds Rehabilitation  
Centre from 23/05/2023 to 19/06/2023.  
She has done an excellent work in  
our organization.

by: Vettukada

Date: 19/06/2023



*Theresa S. John*

Theresa S. John

SPECIAL TEACHER  
BUDS SCHOOL & REHABILITATION CENTRE  
KULATHOOR GRAMA PANCHAYAT





# KERALA STATE ELECTRONICS DEVELOPMENT CORPORATION LTD.

(A Government of Kerala Undertaking)

**KELTRON**  
ISO 9001 : 2015 CERTIFIED

**Keltron Communication Complex** Telephone : 0471-2598948 (5 lines)  
Monvila, Kulathoor P. O.  
Thiruvananthapuram-695 583 Fax : 0471-2598984  
KERALA, INDIA  
CIN: U74999KL1972SGC002450 E-mail : cgmkcc@keltron.org

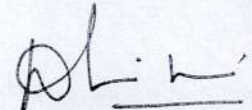
KCC/HRD/PW/2023/305

17/06/2023

## CERTIFICATE

This is to certify that **Ms. Athithya AV**, MSW (HR) 4<sup>th</sup> semester Student of Nanjil Catholic College of Arts and Science, Tamil Nadu has successfully completed her Industrial training during the period from 2<sup>nd</sup> June 2023 to 17<sup>th</sup> June 2023 in our organization as a part of her academic curriculum under our guidance.



  
MINI D L  
SR OFFICER (HR&ADMN)



ISO 9001 : 2015

Date:24-06-2023

## INTERNSHIP COMPLETION CERTIFICATE

This is to certify that Mr. FAUSTIN C, Reg No: 20213102108211 student of NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE KALIYAKKAVILAI , KANYAKUMARI Department of MSW(HR) has successfully completed his HR INTERNSHIP from 24-05-2023 to 24-06 -2023 in our organization.

During the tenure of training, we found his sincere, attentive and good behaviour.



Authorised signature

# CHILDREN'S PARADISE TRUST –LIGHT HOUSE

## **Integrated Rehabilitation Centre for Addicts**

E-mail: childparadise2018@gmail.com, No 1C/183A, Raja Rathinam Nagar,  
Silver Puram, Thoothukudi (DT) – 6286002.

8870883338

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*Date: 15/06/2023*

### TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Miss.Jenisha V.J** did her summer internship in **Children's paradise trust De-addiction centre at Thoothukudi** from **23/05/2023 to 15/06/2023**. During this period, she has managed to do the following

- Conducting and participating in group therapy.
- Observed people with different kinds of drug abuse.
- Observed patients in long term rehabilitation wards for alcoholism and drug de-addiction.
- Shadowed for counseling and therapy sessions given to patients and their families.
- Learned to take case history and mental state examination.

During her internship she has seemed curious and enthusiastic to learn. Her character and attendance was good during this period. I take this opportunity to thank the department of social work for sending her to our de-addiction centre and wish her all the success in future.

Thanking you

**CHILDRENS PARADISE TRUST**  
*Albert*  
**PROJECT DIRECTOR**



## **Jesuit Ministry to Alcohol and Drug Dependents**

Carmel School Campus, Rajakamangalam Road

Nagercoil – 4, **Reg no: 216**

Office: 04652 264343

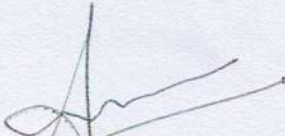
Email ID: [jmaaddngl@gmail.com](mailto:jmaaddngl@gmail.com)

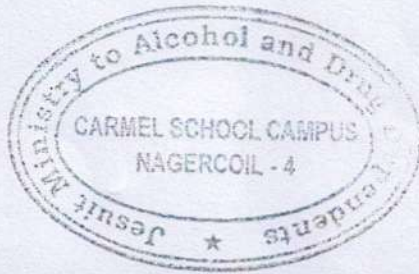
**Administrator: J. Sahaya Franco ExMc (7395847453)**

**Date: 15.06.2023**


### **To Whom it may Concern**

This is to certify that **Ms. Keerthana Christopher C**, student of 2<sup>nd</sup> MSW, Nanjil Catholic College of Arts & Science, Kaliyakkavilai has successfully finished her **Internship Training** on **“Alcoholism and Drug Addiction”** at JMAADD, Integrated Rehabilitation Centre for Alcoholics and Drug Addicts for 20 days from 23<sup>rd</sup> May to 15<sup>th</sup> June 2023. During the training period, her performance and involvement are excellent.

  
**Administrator**





  
**Schizophrenia Research  
Foundation (India)**  
WHO Collaborating Centre for Mental Health Research & Training

Chairman : **Mr. R. Seshasayee**  
Vice Chairman : **Dr. R. Thara**

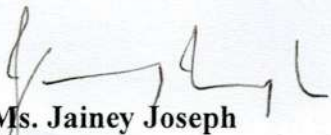
Director : **Dr. R. Padmavati**  
Founder : **Dr. M. Sarada Menon**

**TO WHOMSOEVER IT MAY CONCERN**


This is to certify that Ms. Malini J.S doing her 2<sup>nd</sup> year in Masters in Social Work (MSW), specializing in Medical and Psychiatry at Nanjil Catholic College of Arts and Science, Kanyakumari Tamil Nadu has completed her Internship at Schizophrenia Research Foundation (India) from 1<sup>st</sup> June 2023 – 17<sup>th</sup> June 2023. ( 12 days)

During her training, she was given the opportunity to observe case history taking. She conducted recreational activities and group activities focusing on medication adherence and family burden for our patients attending Vocational Rehabilitation Centre.

We wish her success in her future endeavors.

  
**Ms. Jainey Joseph**  
Agency Supervisor & Co-Ordinator  
Dept. Psychosocial Rehabilitation



  
**Mr. D. Kotteswara Rao**  
Assistant Director  
Community Mental Health &  
Students placement



# SHADITHYA HEALTH CARE

Speciality Hospital for Mental Health, De-addiction and Dementia

## BLOCK PLACEMENT COMPLETION LETTER

DATE: 15/06/2023

TO WHOMSOEVER IT MAY CONCERN

This is to certify that Ms. Maya R, Nanjil Catholic College of Arts and Science, Kaliyakkavilai did her block placement in Social Work Department at SHADITHYA HOSPITAL from 23/05/2023 to 15/06/2023. During this period, she has managed to do the following.

- ❖ Got an opportunity to observe and shadow Psychologists, Psychiatrists, Counsellors, and Social workers.
- ❖ Observed people with different kinds of psychiatric problems in inpatient settings.
- ❖ Attended reviews in acute psychiatric wards with patients who have complex and severe mental health problems.
- ❖ Observed patients in long term rehabilitation wards for alcoholism and drug de-addiction.
- ❖ Shadowed for counselling and therapy sessions given to patients and their families.
- ❖ Learnt to take history and mental state examination.
- ❖ Has done Case Study for Person with Psychiatric Illness
- ❖ Has done Group Activity for patients in rehabilitation centre
- ❖ Has observed during ECT session

During her block placement, she has seemed curious and enthusiastic to learn. Her character and attendance was good.

Should you require further information, please contact me on 22640745/22640845.

*K. Jayandhrakumar*

Mr. K. JAYANDRAKUMAR, MA (SW)  
Social Worker



*Dr. Soumya R.S*

Dr.M.Sree Prathap MBBS, MRC Psych.,  
Chairman Managing Director

## SHADITHYA HEALTH CARE

No.7, Tannery Street, Pallavaram, Chennai - 600 043. Tamilnadu, INDIA.

P: +91 44 2264 0745 / 2264 0845 | E: shadithya2015@gmail.com

Helpline: +91 89397 29999



# SHADITHYA HEALTH CARE

Specialty Hospital for Mental Health, De-addiction and Dementia

## BLOCK PLACEMENT COMPLETION LETTER

DATE: 15/06/2023

TO WHOMSOEVER IT MAY CONCERN

This is to certify that Ms. Mona Jeslin MJ, Nanjil Catholic College of Arts and Science, Kaliyakkavilai did her block placement in Social Work Department at SHADITHYA HOSPITAL from 23/05/2023 to 15/06/2023. During this period, she has managed to do the following.

- ❖ Got an opportunity to observe and shadow Psychologists, Psychiatrists, Counsellors, and Social workers.
- ❖ Observed people with different kinds of psychiatric problems in inpatient settings.
- ❖ Attended reviews in acute psychiatric wards with patients who have complex and severe mental health problems.
- ❖ Observed patients in long term rehabilitation wards for alcoholism and drug de-addiction.
- ❖ Shadowed for counselling and therapy sessions given to patients and their families.
- ❖ Learnt to take history and mental state examination.
- ❖ Has done Case Study for Person with Psychiatric Illness
- ❖ Has done Group Activity for patients in rehabilitation centre
- ❖ Has observed during ECT session

During her block placement, she has seemed curious and enthusiastic to learn. Her character and attendance was good.

Should you require further information, please contact me on 22640745/22640845.

*K. Jayandhakumar*

Mr. K. JAYANDRAKUMAR, MA (SW)  
Social Worker



*Dr. M. Sree Prathap*  
Dr. M. Sree Prathap MBBS, MRC Psych.,  
Chairman Managing Director

## SHADITHYA HEALTH CARE

No.7, Tannery Street, Pallavaram, Chennai - 600 043. Tamilnadu, INDIA.

P: +91 44 2264 0745 / 2264 0845 | E: shadithya2015@gmail.com

Helpline: +91 89397 29999



# KARUNASAI

## DE-ADDICTION & MENTAL HEALTH RESEARCH INSTITUTE

Vellanad, Thiruvananthapuram-695543, Kerala  
Wed: [www.karunasai.com](http://www.karunasai.com), Mail: [karunasai.tvpm@gmail.com](mailto:karunasai.tvpm@gmail.com)  
Tel: +91 472 2883856, +91 9995853075

Date 15/06/2023

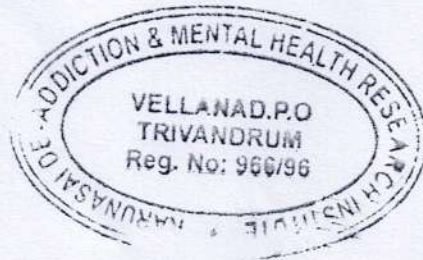
### CERTIFICATE

This is to certify that **Nithya N Saji** a bonafide student of **Nanjil Catholic College of Arts & Science** pursuing her 2<sup>nd</sup> year MSW (Medical and Psychiatry) had successfully completed internship training programme at Karunasai De-addiction & Mental Health Research Institute from 23/05/2023 to 15/06/2023 (15 days).

During the tenure of internship, her conduct was satisfactory and she actively participated in all the activities of **Karunasai De-Addiction & Mental Health Research Institute**. We wish her all the best for her future endeavors.

Training Supervisor

Project coordinator





**(CENTRE FOR RURAL DEVELOPMENT OF INDIA)****Regd under Indian TRUST ACT 1882****Regd under section 12AA of the INCOME TAX ACT 1961****Recognition under section 80-G of the INCOME TAX ACT 1961****(Aided By C.S.W.B - Govt.of India)**

C.R.D. OF INDIA

Paloor Jn, Karungal (P.O),

K.K.Dist, T.Nadu,

S.India-629157,

Ph : 04651-267601

Email : crdofindia@yahoo.com

L. Victor, M.A.,M.Phil.,Ph.D.

Director

Date...16/06/23

No :

**TO WHOM SO EVER IT MAY CONCERN**

This is to certify that Mr. Prabudhas S, II MSW, Department of Social Work, Nanjil Catholic College of Arts & Science, Kaliyakkavilai has successfully undergone his field study in our Organization during the Period 23.05.2023 to 16.06.2023 and his performance during his study was good. We wish his every success in his future career.

By



G.Chandra

(Secretary)

Copy To :

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# **CHILDREN'S PARADISE TRUST –LIGHT HOUSE**

## **Integrated Rehabilitation Centre for Addicts**

E-mail: childparadise2018@gmail.com, No 1C/183A, Raja Rathinam Nagar,  
Silver Puram, Thoothukudi (DT) – 6286002.

8870883338

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*Date: 15/06/2023*

### **TO WHOM SO EVER IT MAY CONCERN**

This is to certify that **Miss.Rasmitha.R** did her summer internship in **Children's paradise trust De-addiction centre at Thoothukudi** from **23/05/2023** to **15/06/2023**. During this period, she has managed to do the following

- Conducting and participating in group therapy.
- Observed people with different kinds of drug abuse.
- Observed patients in long term rehabilitation wards for alcoholism and drug de-addiction.
- Shadowed for counseling and therapy sessions given to patients and their families.
- Learned to take case history and mental state examination.

During her internship she has seemed curious and enthusiastic to learn. Her character and attendance was good during this period. I take this opportunity to thank the department of social work for sending her to our de-addiction centre and wish her all the success in future.

Thanking you

**CHILDRENS PARADISE TRUST**

  
**PROJECT DIRECTOR**



KCC/HRD/PW/2023/303

17/06/2023

**CERTIFICATE**

This is to certify that **Mr. Richu D A**, MSW (HR) 4<sup>th</sup> semester Student of Nanjil Catholic College of Arts and Science, Tamil Nadu has successfully completed his Industrial training during the period from 2<sup>nd</sup> June 2023 to 17<sup>th</sup> June 2023 in our organization as a part of his academic curriculum under our guidance.



  
**MINI D L**  
SR OFFICER (HR&ADMN)



ISO 9001 : 2015

(Estd. 1965)

# MAR THOMA MISSION HOSPITAL, HOSKOTE

(Formerly Hoskote Mission & Medical Centre)

Reg.No.BLR-00084-AA.H.P

Rev. Jinson K. Mathew  
Missionary / Director  
Mob : 09483960085

Rev. Jince P. Koshy  
Asst. Missionary  
Mob : 9747108329

Mr. M.Thomas Mathew  
Treasurer  
Mob : 9880535495

May 17, 2023

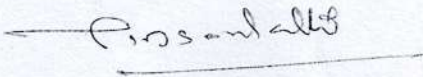
To,  
Mrs. S. Mary Pelsit MSW, M. Phil, NET  
Asst. Prof. & Head, Dept. of Social Work  
Nanjil Catholic College of Arts and Science  
Kaliyakkavilai - 629 153

Dear Madam.

This is to certify that Ms. Sreelekshmi S.S, II M S W (Medical & Psychiatry) has undergone Institutional training from 29<sup>th</sup> May 2023 and completed on 17<sup>th</sup> May 2023 at Mar Thoma Mission Hospital, Hoskote, Bangalore.

During her training period we found her to be self motivated and eager to learn new things. She was hard working and sincere and her character and conduct found to be good.

We wish her all the best.



Rev. Jinson K. Mathew  
Director





**PRERANA HOSPITAL**  
For Neurocare, Psychiatry & De-Addiction

# CERTIFICATE

This certificate is presented to

Ms. SHRUTHYLEKSHMI . S.V

Has completed His / Her internship from a period of 24-05-2023 to 15-06-2023 at  
**Prerana Hospital for Neuro-Care , Psychiatry and De-Addiction.**

During the period of His / Her internship program with us, She / He has been exposed to - detailed case workup and Diagnosis, Counseling / Psychotherapy, Rehabilitation and long term care.

He / She was hard working, motivated and keen to learn.

13/06/23

Date

**Dr. H. R. Abhijit**  
Consultant Neuro-Psychiatrist  
Director - Prerana Hospital

(Estd. 1965)

# MAR THOMA MISSION HOSPITAL, HOSKOTE

(Formerly Hoskote Mission & Medical Centre)

Reg.No.BLR-00084-AA.H.P

Rev. Jinson K. Mathew  
Missionary / Director  
Mob : 09483960085

Rev. Jince P. Koshy  
Asst. Missionary  
Mob : 9747108329

Mr. M.Thomas Mathew  
Treasurer  
Mob : 9880535495

May 17, 2023

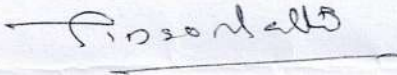
To,  
Mrs. S. Mary Pelsit MSW, M. Phil, NET  
Asst. Prof. & Head, Dept. of Social Work  
Nanjil Catholic College of Arts and Science  
Kaliyakkavilai - 629 153

Dear Madam.

This is to certify that Ms. Surya. J.S., II M S W (Medical & Psychiatry) has undergone Institutional training from 29<sup>th</sup> May 2023 and completed on 17<sup>th</sup> May 2023 at Mar Thoma Mission Hospital, Hoskote, Bangalore.

During her training period we found her to be self motivated and eager to learn new things. She was hard working and sincere and her character and conduct found to be good.

We wish her all the best.



Rev. Jinson K. Mathew  
Director



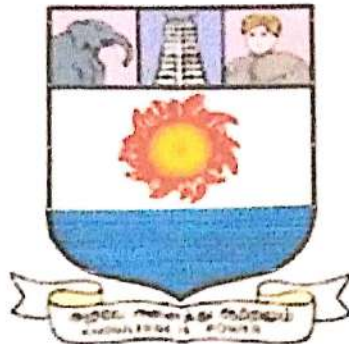
**NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE**

**KALIYKKAVILA – 629153**

**DEPARTMENT OF SOCIAL WORK**

**BLOCK PLACEMENT REPORT**

**SECOND SEMESTER**



**Submitted to**

**Manonmaniam Sundaranar University**

**Thirunelveli in partial fulfillment of**


**the requirement of MSW Degree**

**Submitted by**

**Name: J.S. Adhirsh Joseph**

**Reg.No: 20223102108201**

**MAY 2023**

  
**Signature of guide**

  
**Signature of Examiner**

  
**Signature of HOD**  
Department of Social Work  
Nanjil Catholic College of Arts and Science  
Kaliyakkavilal - 629 153, Tamil Nadu



NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE  
KALIYKKAVILA – 629153

DEPARTMENT OF SOCIAL WORK

BLOCK PLACEMENT REPORT

SECOND SEMESTER



Submitted to

Manonmaniam Sundaranar University

Thirunelveli in partial fulfilment of

the requirement of MSW Degree

Submitted by

Name: J.S. AMAL

Reg.No: 20223102108202102

JUNE 2023

Signature of guide

Signature of Examiner

Head  
Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilal - 629 153, Tamil Nadu.





NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE  
KALIYKKAVILA – 629153

DEPARTMENT OF SOCIAL WORK

BLOCK PLACEMENT REPORT

SECOND SEMESTER



Submitted to

Manonmaniam Sundaranar University

Thirunelveli in partial fulfillment of


the requirement of MSW Degree

Submitted by

Name : Anila D P

Reg. No : 20223102108203

April 2023

  
Signature of guide

  
Signature of Examiner



  
Signature of Head  
Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavila - 629 153, Tamil Nadu.

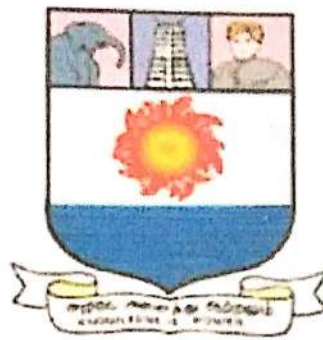
**NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE**

**KALIYKKAVILA – 629153**

**DEPARTMENT OF SOCIAL WORK**

**BLOCK PLACEMENT REPORT**

**SECOND SEMESTER**



**Submitted to**

**Manonmaniam Sundaranar University**

**Thirunelveli in partial fulfilment of**


**the requirement of MSW Degree**

**Submitted by**

**Name: Anishma M J**

**Reg.No: 20223102108204**

**June 2023**

  
**Signature of guide**

  
**Signature of Examiner**

  
**Signature of Head**  
**Department of Social Work**  
**Nanjil Catholic College of Arts & Science**  
**Kaliyakkavilai - 629 153, Tamil Nadu.**





# Kanyakumari Social Service Society

Fr. Thomas Sebastian Poovathumoottil, Director  
Kalluvilai, Mulagumoodu P.O., Kanyakumari District, Tamilnadu, India Pin 629 167  
Call: +91 4651 275160 / 9884561965 | kssstf@yahoo.com/www.kss.org

Date 19.06.2023

## CONCURRENT FIELD WORK TRAINING CERTIFICATE

This is to certify that Miss. A.S.Anju MSW student of Nanjil Catholic Collage of Arts and Science, Kaliyakkavilai Placed in Kanyakumari Social Service Society Kalluvilai has undergone Concurrent field work training from 29th May 2023 to 19th April 2023.

She has been given training in all aspects of the organization and his fieldwork involved Group Work, a Community organization programme, project implementation work & Casework.

During this period, her work, Character and conduct are found good. We wish a great success in her future academic field and Social Action

Fr. Thomas Sebastian

Director, KKSSS

KANYAKUMARI SOCIAL SERVICE SOCIETY  
Kalluvilai, Mulagumoodu P.O.  
K.C. Dist., Tamil Nadu - 629 167



# Kanyakumari Social Service Society

Fr. Thomas Sebastian Poovathumoottil, Director  
Kalluvilai, Mulagumoodu P.O., Kanyakumari District, Tamilnadu, India. Pin 629 167  
Call: +91 4651 275160 / 9884561965 | kksstk@yahoo.com/www.kksss.org

Date: 19.06.2023

## CONCURRENT FIELD WORK TRAINING CERTIFICATE

This is to certify that Miss.C.S.Blessing Jikki MSW student of Nanjil Catholic Collage of Arts and Science, Kaliyakkavilai Placed in Kanyakumari Social Service Society Kalluvilai has undergone Concurrent field work training from 29th May 2023 to 19th April 2023.

She has been given training in all aspects of the organization and his fieldwork involved Group Work, a Community organization programme, project implementation work & Casework.

During this period, her work, Character and conduct are found good. We wish a great success in her future academic field and Social Action

Fr. Thomas Sebastian

Director, KKSSS

KANYAKUMARI SOCIAL SERVICE SOCIETY

Kalluvilai, Mulagumoodu P.O.

K. K. Dist. Tamil Nadu - 629 167



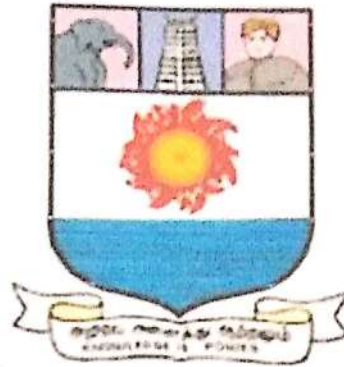
NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE

KALIYKKAVILA – 629153

DEPARTMENT OF SOCIAL WORK

BLOCK PLACEMENT REPORT

SECOND SEMESTER



Submitted to

Manonmaniam Sundaranar University

Thirunelveli in partial fulfillment of

the requirement of MSW Degree

Submitted by

Name: D.Dejin Jose

Reg.No: 20223102108207

MAY 2023

Signature of guide

Signature of Examiner

Signature of HOD



Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilal - 629 153, Tamil Nadu.



# SURAKSHA COMMUNITY CENTRE FOR FAMILY HEALTH

Aided by

Central Social Welfare Board, Govt. of India, TNSWB

15/150-G, TVM Road, Thottiyodu, Chunkankadai (P.O), Kanyakumari District

NGO Unique Id : TN/2014/0079717

Phone: 04651 – 258077

E-mail : sscefh@yahoo.co.in

Mrs. Santha Balakrishnan  
Chairman

Prof. Dr. Swarnalatha Raju  
Vice-Chairman

Mrs. Lakshmi. S.Nair  
Secretary

Mrs. Anitha Natarajan  
Treasurer

19.06.2023

## FIELD WORK CERTIFICATE

This is to certify that **B. P. DELPHIN**, who is studying I year M.S.W at Nanjil Catholic College of Arts and Science, Kaliyakkavilai, has undergone Field Work in our Organization from 29/05/2023 to 19/06/2023. During her period, she was punctual, committed and interacted well.

I wish her all success in her endeavor.

Prof. Dr. Swarnalatha Raju

**VICE CHAIRMAN**

SURAKSHA COMMUNITY CENTRE  
FOR FAMILY HEALTH  
15/150-G, TVM Main Road, Thottiyode  
Chunkankadai (P.O), K.K. Dist.-629003  
☎ 04652 - 222037



**NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE**

**KALIYAKKAVILAI - 629 153**

**DEPARTMENT OF SOCIAL WORK**

**2022-2023**

**BLOCK PLACEMENT REPORT**

**SECOND SEMESTER**



**Submitted to**

**Manonmaniam Sundaranar University**

**Thirunelveli in partial fulfillment of the**

**Requirement for MASTER OF SOCIAL WORK Degree**

**Submitted by,**

**Name: JOFIN JOSEPH**

**Reg. No: 20223102108211**

**Signature of Guide**

**Signature of the Examiner**

**Signature of HOD**  
Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153, Tamil Nadu.





# SURAKSHA COMMUNITY CENTRE FOR FAMILY HEALTH

Aided by

Central Social Welfare Board, Govt. of India, TNSWB

15/150-G, TVM Road, Thottiyodu, Chunkankadai (P.O), Kanyakumari District

NGO Unique Id : TN/2014/0079717

Phone: 04651 - 258077

E-mail : sscfch@yahoo.co.in

Mrs. Santha Balakrishnan  
Chairman

Prof. Dr. Swarnalatha Raju  
Vice-Chairman

Mrs. Lakshmi S.Nair  
Secretary

Mrs. Anitha Natarajan  
Treasurer

19.06.2023

## FIELD WORK CERTIFICATE

This is to certify that **D. JEFLIN**, who is studying I year M.S.W at Nanjil Catholic College of Arts and Science, Kaliyakkavilai, has undergone Field Work in our Organization from 29/05/2023 to 19/06/2023. During her period, she was punctual, committed and interacted well.

I wish her all success in her endeavor.

Prof. Dr. Swarnalatha Raju

**VICE CHAIRMAN**

SURAKSHA COMMUNITY CENTRE  
FOR FAMILY HEALTH  
15-150-G, TVM Main Road, Thottiyode  
Chunkankadai (P.O.), K.K. Dist. -629003  
☎ 04652 - 222037







**SPS INDIA FOUNDATION**  
(Social Profit Skilling in Shevaroy Hills)

18.06.2023

### CERTIFICATE OF EXPERIENCE

This is to certify that Mr. Jacob M., 1<sup>st</sup> year student of MSW from Nanjil Catholic College of Arts and Science, Kaliyakkavilai Po., Kanniyakumari Dt., has done his internship in SPS India foundation trust of the Retreat - Don Bosco, Yercaud from 29<sup>th</sup> of May to 18<sup>th</sup> of June 2023.

During his internship he effectively carried out the activities (such as - organizing the students who are part of the educational scholarship provided by the trust, organizing basic computer course for the same students and conducting a scientific study about the tribal children who applied to be part of the home for the tribal children – run by the trust) entrusted to him and was open to learn about the local culture and the tribal people. The student was committed and showed lot of positive spirit during the period of his internship.

We wish him all the best for his upcoming career.

Thanking you,

**Fr. Selvakumar SDB**  
Director of the Social Work  
SPS India Foundation  
The Retreat Don Bosco,  
Yercaud – 636 601  
Salem District.

SPS INDIA FOUNDATION  
The Retreat  
YERCAUD - 636 601.  
Salem District

The Retreat, YERCAUD - 636 601  
Salem District, Tamil Nadu, INDIA

Phone : +91 4281 2221 38  
Mobile : +91 99621 46828

info@spsindiafoundation.in  
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NANJIL CATHOLIC COLLEGE OF ARTS AND SCIENCE  
KALIYKKAVILA – 629153

DEPARTMENT OF SOCIAL WORK

BLOCK PLACEMENT REPORT

SECOND SEMESTER



Submitted to

Manonmaniam Sundaranar University

Thirunelveli in partial fulfillment of

the requirement of MSW Degree

Submitted by

Name : Leena Jose

Reg. No : 20223102108212

April 2023

  
Signature of guide

Signature of Examiner

  
Signature of Head  
Head  
Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilai - 629 153, Tamil Nadu.

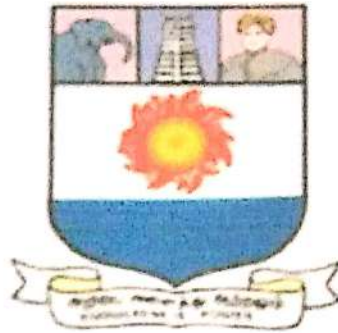


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Submitted by

Name: Lekshmi Santosh

Reg.No: 20223102108213

June 2023

  
Signature of guide

Signature of Examiner

  
Signature of HOD  
Department of Social Work  
Nanjil Catholic College of Arts & Science  
Kaliyakkavilal - 629 153, Tamil Nadu.





**MALANKARA MAR THOMA SYRIAN CHURCH  
CHENGANNUR-MAVELIKARA DIOCESE**

**Dr. Zacharias Mar Theophilus Suffragan Metropolitan Memorial  
Tharangam Mission Action Centre**

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**TO WHOM IT MAY CONCERN**

This is to certify that Mr Subin Geo Thomas, S/O Thomas George, Puthenparambil, Pathanapuram, student of Nanjil Catholic College, Kaliakavila served from 28<sup>th</sup> MAY TO 17<sup>th</sup> June 2023 at Tharangam Mission Action Centre and Mar Chrysostom Palliative Centre as part of his Block Placement.

During his tenure, he displayed utmost dedication and commitment to his volunteer role. He actively participated in various activities and carried out his responsibilities with sincerity and consistently demonstrated his enthusiasm to support our activities. His positive attitude and willingness to take on any task assigned to him were commendable. During his time with us, Mr. Subin Geo Thomas, actively engaged in our initiatives, including but not limited to Athmeeya Tharangam, Karuthal, Samrudhi and Ashwas projects.

We firmly believe that his passion, skills, and work ethic will continue to be an asset wherever he chooses to contribute his talents. We wish Mr. Subin Geo Thomas every success in his future endeavors.

Rev Jyothish Sam  
Director  
18 June 2023

