# Synthesis, Applications and Future perspectives of CdTe and CdS thin films: A Review

*[1]Ajay A. Nikam, [2]Ugalal P. Shinde

[1, 2]Department of Electronic Science and Research Center, LVH Arts, Science and Commerce College, Nashik, Affiliated to SPPU, Pune, Maharashtra, India.
[2]Mahant Jamanadas Maharaj Arts Commerce and Science College, Karanjali, Dist-Nashik, Affiliated to SPPU, Pune, Maharashtra, India.

**Abstract:**
Thin films refer to layers of material with a thickness ranging from a few nanometers to several micrometers. These films are used in a variety of scientific, technological, and industrial applications due to their unique properties. Thin films are fundamental to a wide array of technologies, and ongoing research continues to expand their applications and enhance their properties for future innovations. CdTe (Cadmium Telluride) and CdS (Cadmium Sulfide) thin films are a type of semiconductor material that is commonly used in various applications such as solar cells, photovoltaic cells, photodetectors, optical sensors, gas sensors, and electronic and optoelectronic devices. Due to the unique properties of CdTe and CdS thin films, researchers are now focusing their work on the synthesis and applications of CdTe and CdS thin films. CdTe is a compound semiconductor composed of cadmium and tellurium elements. While CdS is another compound semiconductor composed of cadmium and sulfur. This review paper encompasses a detailed study of CdTe and CdS thin films. It also provides brief information on pure and doped CdTe and CdS thin film fabrication, synthesis approaches and applications.

**Keywords:** Thin films, Cadmium Telluride, Cadmium Sulfide, photovoltaic cells, semiconductors.

## 1. Introduction:

Thin films play a significant role in the 21$^{st}$ century in advancing renewable energy sources, particularly in the field of solar energy. Thin film technologies offer unique advantages in terms of cost, flexibility, and scalability [1]. Thin film technologies often have a lower environmental impact compared to traditional solar cell manufacturing processes, particularly as they require fewer raw materials and energy during production. Researchers are exploring advanced materials and concepts, such as perovskite thin film solar cells, which have shown great promise in terms of efficiency and cost-effectiveness [1, 2]. The impact of technology on human beings and renewable energy sources is multifaceted, influencing various aspects of our lives, environment, and energy systems. Ongoing research and development in renewable energy technologies contributes to the discovery of new and more efficient ways to generate clean power [4]. Despite progress, challenges like energy storage limitations, intermittency issues, and the environmental impact of manufacturing renewable technologies need continuous attention. With the advancement of technology, there might eventually be an energy catastrophe on the planet. Resolving the global energy crisis requires the use of copious renewable energy sources, one of which is solar energy. Solar radiation is converted to electrical energy by solar cells. Recent studies have concentrated on utilising Cadmium Telluride (CdTe) and Cadmium Sulphide (CdS) heterojunction techniques to increase the efficiency of photovoltaic as well as solar cells. CdTe and CdS are both II-VI compound semiconductors with a direct band gap [5, 6]. At room temperature, the band gap of CdTe and CdS is approximately 2.42 electron volts and 1.72 electron volts, respectively. The band gap energy can be tuned by controlling the deposition conditions, making them suitable for different applications [6, 7]. CdTe and CdS exhibit good optical properties, with a wide range of transparency in the visible spectrum. CdS is commonly used as a buffer layer in thin-film solar cells [8]. CdTe has a high absorption coefficient for sunlight, allowing for the efficient conversion of photons into electrical energy. CdS thin films are used in the construction of photodetectors due to their sensitivity to light. CdS is incorporated into thin-film transistor structures for electronic devices. CdS thin films are doped with other elements to modify their electrical and optical properties. Continuous research is being conducted to improve the efficiency and stability of CdS thin films in various applications, especially in the field of solar energy [9, 10].

## 2. Literature review:

The highly efficient solar cell was designed from the start using CdS as the n-type partner in the junction creation process with the p-type CdTe absorber. A significant portion of the early research on solar cells focused on the development of the layers and the junction, but it quickly became apparent that the methods for depositing the absorber and creating the junction were not crucial. The CdTe/CdS layer stacks as-deposited required post-deposition treatment. Subsequently, the scientists directed their attention towards the remaining layers. Firstly, they enhanced the front-contact, considering transparency and chemical stability. Cadmium stannate (CTO), an extremely transparent and highly conductive substance, took the place of indium tin oxide (ITO), aluminum doped zinc oxide (ZAO), and fluorine doped tin oxide (FTO). Numerous fabrication facilities established in the 2000s attest to the fact that CdTe technology has reached a level of stability suitable for commercial development; at present, CdTe production capacity accounts for over seven percent of solar energy production worldwide. In this section various types of synthesis and fabrication methods of thin films of CdS and CdTe are explain according to previous work done be many researchers.

A green synthesis method for synthesized CdS quantum dots with a particle size of 2-4 nm was described by Shivaji et al. Tea leaf extract was used as a toxic-free particle-stabilizing agent. In order to produce CdS QDs biologically, an extract was mixed with a specific quantity of $CdSO_4$ and left in the dark for three days. Next, $Na_2S$ was added, and the mixture was left for a further four days. After centrifuging and lyophilizing the bright yellow solution, more characterization investigations might be conducted. Finally, a well-diffusion experiment was used to demonstrate their antibacterial activity, and A549 cancer cells were used to illustrate the lethal effect of CdS quantum dots [11].

Sahay, P.P., et al [12] prepared CdS thin films by thermal evaporation technique at room temperature. The films were prepared on glass substrates. The vacuum of about 2 x $10^{-5}$ torr was used during preparation of thin films. Author reported that, the films were found to exhibit high transmittance (∼ 60 - 93 %), low absorbance and low reflectance in the visible/near infrared region from ∼ 500 nm to 1100 nm. The optical band gap energy was found to be in the range 2.28 – 2.53 eV. Author also studied the comparatively study of as deposited and annealed films at 300°C for 4 hours and reported that the annealing the films shows the decrease in the optical transmittance and optical band gap. Due to annealing the crystallinity of the films improves, resulting in decrease in the optical transmittance.

CdS thin films were produced onto glass substrates using the vacuum evaporation process by Senthil, K., et al. [13]. According to the author, prepared films primarily exhibit a hexagonal phase with small crystallites. RBS analysis reveals that the films have good stoichiometry. For the annealed films, a decrease in the band gap is seen. The rise in grain size is responsible for the reduction in band gap.

M.A. Mahdi et al. [14] Chemical bath deposition has been used to produce CdS thin films on glass substrates. A source of $Cd^{+2}$ was cadmium acetate. Three sequences of deposition, a 100 nm CdS thin film is produced. The precise technique of chemical bath deposition, which is employed in this work, can be used to create stiochiometric CdS thin films. The thin films' structural analysis reveals that they have a single phase of hexagonal wurtzite as-deposited. While the hexagonal structure is more stable than the cubic structure in solar cells and other optoelectronic devices, other reported works that used the CBD approach to make CdS films obtained cubic structure or mixed phases, cubic and hexagonal. The thin films can be used as a window layer in solar cells because of their excellent transparency in the visible portion of the electromagnetic spectrum.

Ashour and colleagues et al. [15] thin films of cadmium sulfide (CdS) have been created using the chemical spray-pyrolysis method. The substrates were cleaned glass. The substrate temperature was adjusted between 200 and 400 °C, and it appears that this is one of the key factors influencing the semiconductor's physical characteristics. According to the authors, single-phase hexagonal CdS was present in the XRD patterns. It was noticed that the resistivity of the as-deposited films varied according to the substrate temperature, falling between $10^3$ and $10^5$ \Omega. Cm. Optical absorption experiments yielded direct band gap values between 2.39 and 2.42 eV.

CdTe thin films were created by Gordillo, G., et al. [16] by a novel process based on the close-spaced sublimation method. It was possible to construct an evaporation system based on the CSS approach. The ideal circumstances have been described, and the impact of various deposition factors has been examined. The findings of the authors indicate that the substrate and evaporation temperatures, as well as the pressure of the vapour formed by the separated species from the CdTe source in the reaction chamber, have a major impact on the electrical resistivity of the CdTe films. Tiny amounts of oxygen added to the reaction chamber can significantly lower the CdTe films' resistivity.

Thermally evaporated CdTe thin film electrical structure, structural characteristics, and optical properties were investigated by Lalitha, S., et al. [17]. The process of thermal evaporation was used to create thin films of CdTe on glass substrates. It is discovered through X-ray diffractogram analysis that the CdTe films are found to be polycrystalline nature.

Salaoru, I., et al. [18] studied heterojunctions were obtained by successive thermal evaporation under vacuum onto unheated $SnO_2$ coated glass substrates of CdS and CdTe films, respectively. The refractive, transmittance, extinction, and absorption coefficients were measured. The morphological and structural studies of the above mentioned heterojunction component films, in comparison with those of CdS and CdTe films, deposited separately, onto glass substrates, were carried out using transmission electron microscopy, X-ray diffraction and atomic force microscopy techniques.

## 3. Synthesis methods for CdTe and CdS nanoparticles

There are several ways to synthesis of CdTe and CdS nanoparticles, and each has benefits and drawbacks of its own. The required qualities of the nanoparticles and their particular use will determine which synthesis process is used. Finding new methods for the synthesis of CdTe and CdS nanoparticles as well as nanocomposites is the best way to control and modify the size and shape of the nanomaterials [20, 21]. These are fundamental challenges in material science because the size and shape of nanomaterials could reveal new and unknown characteristics. High-quality nanoparticles with the right sizes, shapes, and other structural features can be produced by adjusting the parameters involved in different synthesis techniques as well as the thermodynamics and kinetics conditions during synthesis [21, 22]. Fig. 1 shows that the summary of the various methods used for CdTe and CdS nanoparticles synthesis.

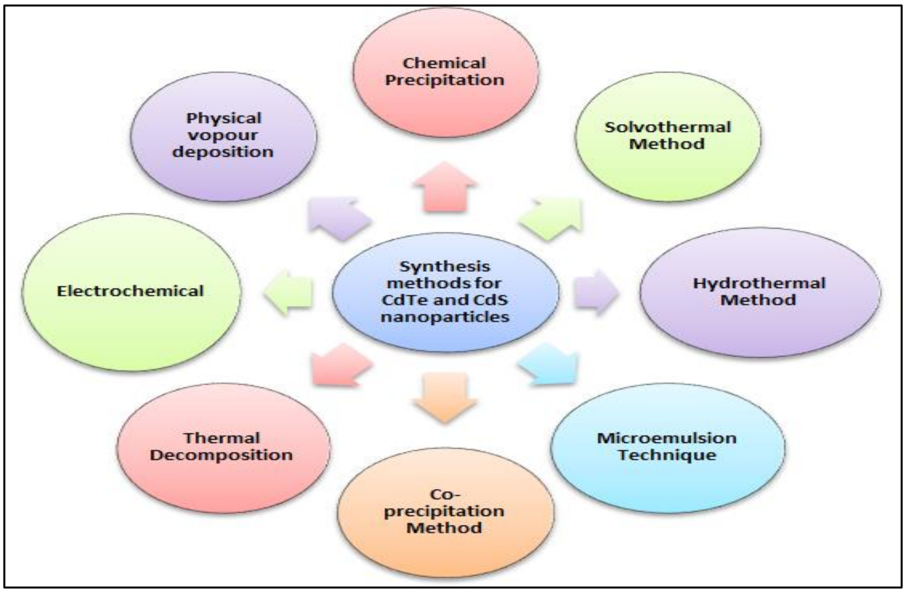


**Figure 1:** Synthesis methods used for CdTe and CdS nanoparticles

### 2. 1 Chemical Precipitation:

CdTe and CdS nanoparticles can be synthesized by chemical precipitation methods. In this method, cadmium ions are reacted with telluride or sulfide ions in a suitable solvent, leading to the formation of nanoparticles. The reaction conditions, such as temperature and pH, play a crucial role in controlling the size and morphology of the nanoparticles.

### 2. 2. Solvothermal Method:

Solvothermal synthesis involves the reaction of precursors in a high-temperature solvent under autogenous pressure. This method allows for the controlled growth of nanoparticles with well-defined shapes and sizes. The choice of solvent and reaction conditions influences the properties of the resulting nanoparticles. One of the best methods for synthesizing CdS NPs is the solvothermal technique. In this process, precursors react in a closed system with a solvent present at a temperature higher than the solvent's boiling point. The size and form of the result can be controlled by adjusting the processing parameters of the reaction system, which include the types of reactants and solvents, temperature, and time.

### 2. 3. Hydrothermal Method:

Similar to the solvothermal method, the hydrothermal method involves the reaction of precursors in water at elevated temperatures and pressures. This method is advantageous for producing highly crystalline nanoparticles with controlled sizes and shapes. The reaction time, temperature, and precursor concentrations can be tuned to achieve desired properties.

### 2. 4. Microemulsion Technique:

Micro-emulsion is an effective technique that produces a range of monodispersion NPs with different sizes and shapes. In essence, it is a thermodynamically stable, isotropic system comprising two immiscible liquids stabilised by a surfactant. Micro-emulsions are ideal for producing NPs because the surfactant-stabilized droplet phase can be viewed as a "nanoreactor" for synthesis. Surface tension causes all nanoreactors to be spherical, and they all equilibrate to the same size over time. Microemulsion involves the use of surfactants to form small droplets of water in an oil phase. CdTe or CdS precursors are introduced into these droplets, leading to nanoparticle formation. This method allows for good control over particle size and shape. Additionally, it provides a stable environment for the reaction.

**2. 5. Co-precipitation Method:**
In this method, both cadmium and tellurium or sulfur precursors are added simultaneously to a solution, leading to the co-precipitation of CdTe or CdS nanoparticles. The reaction conditions, including temperature, pH, and precursor concentrations, are critical in controlling the nanoparticle properties.

**2. 6. Thermal Decomposition:**
CdTe and CdS nanoparticles can be synthesized through the thermal decomposition of organometallic precursors. Cadmium and tellurium or sulfur-containing compounds are heated to high temperatures, resulting in the formation of nanoparticles. This method is often used in the presence of stabilizing agents to control the size and prevent aggregation.

**2. 7. Electrochemical Synthesis:**
Electrochemical methods involve the electrodeposition of CdTe or CdS nanoparticles onto a conductive substrate. By controlling the electrodeposition parameters, such as potential and deposition time, it is possible to tailor the properties of the resulting nanoparticles.

**2. 8. Physical vapour deposition**
The Physical Vapor Deposition (PVD) techniques can also be employed for the synthesis of nanoparticles, particularly by utilizing methods such as evaporation or sputtering. The main idea is to generate a vapor phase of the material and then allow it to condense into nanoparticles.

**2.9 Green synthesis**
Green synthesis methods for the production of nanoparticles involve utilizing environmentally friendly and sustainable approaches, often employing natural resources or benign materials. These methods aim to replace traditional chemical synthesis routes that may involve toxic chemicals or harsh conditions. Green synthesis refers to environmentally friendly methods of producing various materials, chemicals, or compounds. This method is typically used for benign solvents, renewable resources, or safer reaction conditions, minimizing the generation of hazardous waste and reducing environmental impact.

**4. Preparation techniques of CdTe and CdS thin films**
The preparation techniques for CdTe and CdS thin films involve various methods [18-24]. Few methods are illustrated in Table 1.

**Table 1:** Summary of preparation techniques of CdTe and CdS thin films

| Sr. No. | Method | Procedure | Advantages |
|---|---|---|---|
| 1 | Chemical Bath Deposition | Substrates are immersed in a chemical bath containing precursors for the thin films. | Simple and cost-effective.<br>Suitable for large-area depositions. |
| 2 | Physical Vapor Deposition | Selected NPs evaporated using resistive heating, and the vapor condenses on the substrate. | Good control over film thickness.<br>High purity of deposited films. |
| 3 | Selenium Backfilling | CdTe thin films are initially deposited with a deficiency of tellurium. | Improves the stoichiometry of CdTe thin films. |

| | | | |
|---|---|---|---|
| | | | Enhances the efficiency of thin-film solar cells. |
| 4 | Electrochemical Deposition | Electrolyte solutions containing cadmium and tellurium or sulfur ions are used.<br>A voltage is applied to the substrate, leading to the electrochemical reduction of ions and the deposition of CdTe or CdS thin films. | Good control over film properties.<br>Suitable for complex substrate geometries. |
| 5 | Spin Coating | A solution containing cadmium and tellurium or sulfur precursors is dispensed onto a rotating substrate.<br>Centrifugal force spreads the solution, forming a uniform thin film. | Simple and widely used for laboratory-scale depositions.<br>Suitable for small-area depositions. |
| 6 | Chemical Vapor Deposition | Gaseous precursors containing cadmium and tellurium or sulfur are introduced into a reaction chamber.<br>A chemical reaction at the substrate surface leads to the deposition of thin films. | High control over film properties.<br>Suitable for large-scale production. |
| 7 | Close-Spaced Sublimation | Cadmium and tellurium or sulfur sources are placed close to the substrate.<br>Heat is applied, causing the sublimation of materials, and the vapor deposits onto the substrate. | Suitable for large-area depositions.<br>Allows for control over the stoichiometry of the films. |

## 5. Applications of CdTe and CdS thin films

CdTe and CdS thin films used in many applications for various technological fields due to their unique semiconductor properties [25-29]. Few notable applications of CdTe and CdS thin films are display in Fig. 2.

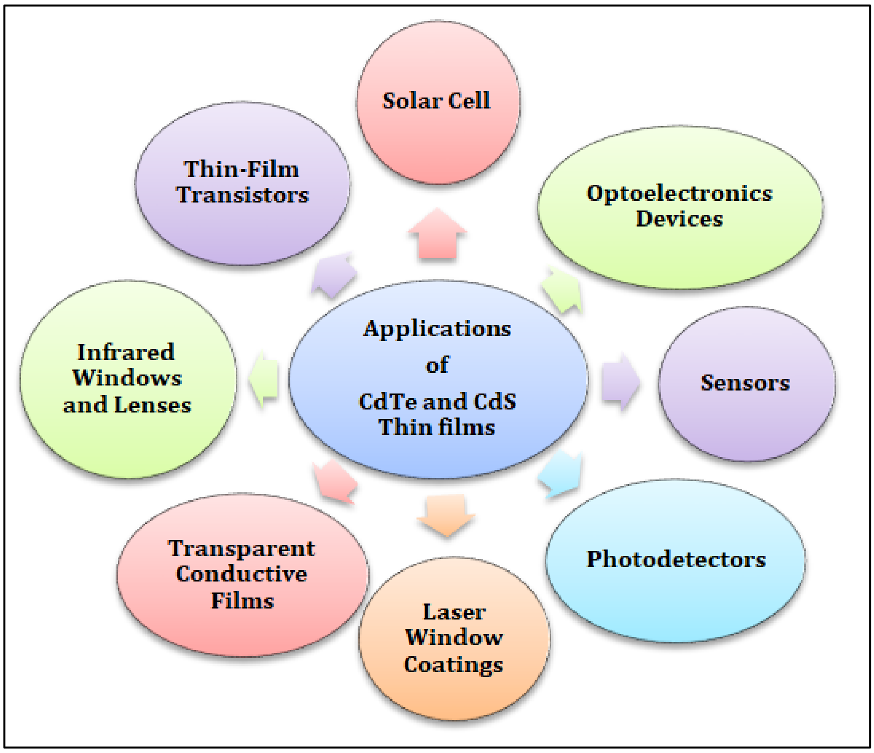


**Figure 2:** Applications of CdTe and CdS nanoparticles

### 5.1 Applications of CdTe Thin Films:

i. **Photovoltaics/Solar Cells:** CdTe thin films are widely used in the production of thin-film solar cells. CdTe solar cells are known for their high absorption coefficient, making them efficient in converting sunlight into electricity. They are used in both small-scale applications (e.g., portable solar chargers) and large-scale photovoltaic power plants.

ii. **X-ray and Gamma-ray Detectors:** CdTe is employed in the construction of X-ray and gamma-ray detectors due to its high atomic number and good stopping power for high-energy photons. These detectors are used in medical imaging, security screening, and industrial applications.

iii. **Infrared Windows and Lenses:** CdTe thin films are used in infrared optics for applications such as windows and lenses. The material's transparency in the infrared region makes it suitable for these purposes.

iv. **Thin-Film Transistors (TFTs):** CdTe thin films can be used in thin-film transistor technology. TFTs are essential components in electronic devices like flat-panel displays, sensors, and integrated circuits.

### 5.2 Applications of CdS Thin Films:

i. **Photovoltaics/Solar Cells:** CdS thin films are often used as a buffer layer in thin-film solar cells, improving the efficiency of the devices. They contribute to the overall performance and stability of solar cell structures.

ii. **Optoelectronic Devices:** CdS thin films are employed in optoelectronic devices such as light-emitting diodes (LEDs) and lasers. The material's semiconductor properties make it suitable for converting electrical energy into light.

iii. **Photodetectors:** CdS is used in the construction of photodetectors, devices that detect and convert light signals into electrical signals. This is valuable in applications like optical communication systems and imaging devices.

iv. **Sensors:** CdS thin films are utilized in various sensor applications, including gas sensors and photoconductors. The sensitivity of CdS to changes in light or certain gases makes it suitable for detecting environmental changes.

v. **Laser Window Coatings:** CdS thin films are used as coatings for laser windows. These coatings help control the transmission and reflection of laser beams, improving the efficiency and performance of lasers in various applications.

vi. **Transparent Conductive Films:** CdS thin films are employed as transparent conductive films in devices such as touch screens, solar cells, and flat-panel displays. They offer a combination of transparency and conductivity.

## 6. Future perspectives of CdTe and CdS thin films

The future perspectives of CdTe and CdS thin films involve ongoing research and development efforts aimed at improving their performance, expanding their applications, and addressing environmental concerns associated with the use of cadmium. Ongoing research focuses on enhancing the efficiency of CdTe-based thin-film solar cells [29, 30]. Innovations in material engineering, device architectures, and manufacturing processes aim to make CdTe solar cells even more competitive with other solar technologies. Tandem solar cells, which combine multiple materials with complementary absorption characteristics, are being explored to achieve higher efficiencies. Combining CdTe with other materials in tandem structures could offer improved performance in capturing a broader range of the solar spectrum. CdTe and CdS thin films may find new applications in building-integrated photovoltaics (BIPV), where solar cells are integrated into architectural elements like windows, facades, and roofing materials. Such integration can contribute to the widespread adoption of solar energy in urban environments. CdTe and CdS thin films may be explored for use in energy storage applications, such as supercapacitors and batteries. Research is ongoing to understand and optimize the electrochemical properties of these materials for efficient energy storage.

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# Investigation of Electrical and Optical Properties of CdS Thin Films Prepared by Physical Vapour Deposition Technique

*[1]Ajay A. Nikam, [2]Ugalal P. Shinde

[1, 2]Department of Electronic Science and Research Center, LVH Arts, Science and Commerce College, Nashik, Affiliated to SPPU, Pune, Maharashtra, India.
[2]Mahant Jamanadas Maharaj Arts Commerce and Science College, Karanjali, Dist-Nashik, Affiliated to SPPU, Pune, Maharashtra, India.
**Corresponding author:** ajay831330@gmail.com

*Abstract*: **Due to its many uses in optoelectronic devices, cadmium sulfide is one of the most interesting semiconducting materials. With the chemical formula CdS, it is a binary compound. It is a semiconductor compound in the II–VI range with a 2.4 eV intermediate energy band gap. Its high sensitivity to light and high absorption coefficient make it useful in the field of renewable energy conversion. Among the many uses for CdS thin films, one is as a window layer in second-generation solar cells, where it produces photon traps and thus quantum efficiency. In this work, the physical vapor deposition technique is used to fabricate CdS thin films on glass substrates, and the electrical and optical properties of the prepared films were investigated. The resistivity of CdS thin film was found to be 36.881 Ω.cm. TCR of the film was observed -0.001948 /°C. The prepared films also exhibits good optical properties.**

***Keywords: Cadmium sulfide, binary compound, deposition technique, electrical and optical properties***

## 1. Introduction:

The fabrication of sophisticated electrical devices, optical elements, and several other uses are made possible by thin films, which are essential to the advancement of technology [1]. Scientists and engineers continuously research new materials and deposition techniques to improve the performance and characteristics of thin films [1, 2]. They are crucial in many sectors because of the exact control they have over the thickness and qualities of the film. Substratum layers with thicknesses ranging from nanometers (nm) to micrometers (µm) can be recognized as thin films [3, 4]. These films have several uses in a wide range of technical applications and are frequently placed onto a substrate. Physical Vapor Deposition (PVD) is a category of thin film deposition techniques that involve the physical processes of vaporization and condensation to create a thin film on a substrate. PVD methods are widely used in various industries for applications ranging from microelectronics to optics and decorative coatings. In PVD, the material to be deposited (the source material) is physically vaporized or sputtered from a solid or liquid state into a vapor phase [5-7]. The vaporized material then condenses on a substrate, forming a thin film. PVD is used in a wide range of applications, including the deposition of metal and semiconductor films for microelectronics, the production of optical coatings, decorative coatings on jewelry and watches, and the manufacturing of solar cells. PVD methods are relatively clean and can be performed under vacuum conditions, minimizing contamination. It is essential for preparing thin films with specific properties, and they play a crucial role in the production of various advanced materials and devices [8, 9]. CdS is a semiconductor with a direct bandgap. The bandgap energy of CdS is around 2.42 eV, making it suitable for optoelectronic applications [10]. The electrical properties of CdS thin films are important for various applications, especially in the field of electronics and optoelectronics. The electrical behavior of CdS thin films is influenced by factors such as the deposition method, film thickness, crystallinity, and doping [11, 12]. The different methods of thin films deposition or fabrications are reveals in Fig.1.

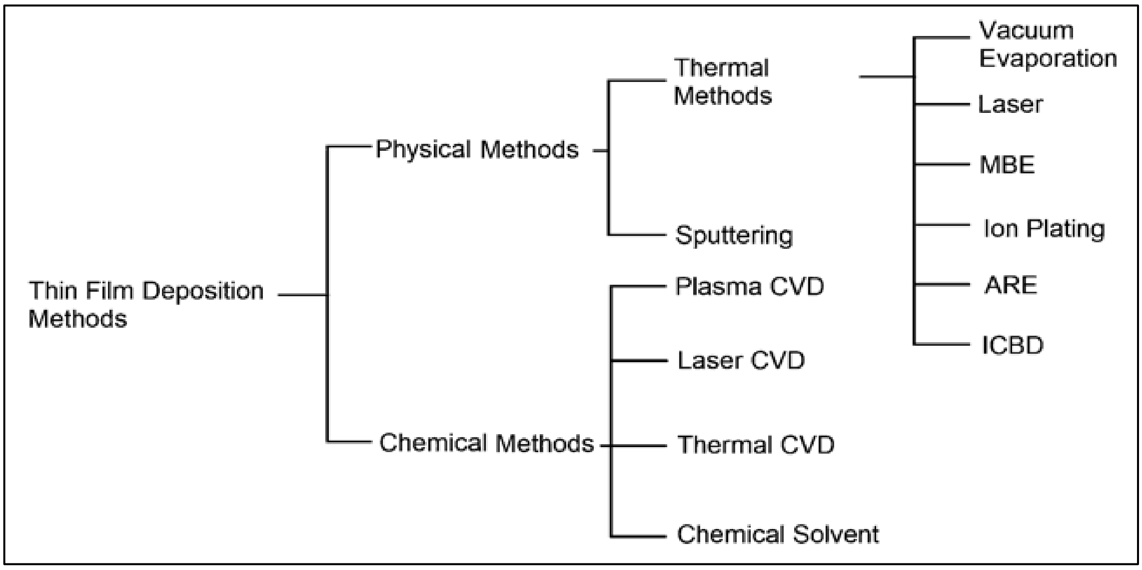


**Figure 1:** Methods of thin films fabrication

The aim of present research work is to preparation of CdS thin films by Physical vapour deposition technique and investigation of electrical and optical properties of the CdS films.

## 2. Experimental Work

Commercially available AR-grade CdS nanoparticles were used in this research work. The CdS nanoparticles (NP's) were purchased from Sigma Enterprises, Nashik. All of the films were prepared on glass substrates. For the preparation of thin films, all substrates were washed with acetone and then exposed to an IR lamp for 20 minutes to eliminate other contaminants. The thermal-evaporated technique was used to prepare thin films. The system consists of a vacuum pump system that was evacuated to a pressure of $10^{-5}$-$10^{-6}$ mbar. A vacuum was created inside the chamber, and substrates were placed inside the vacuum glass chamber. CdS NP's were retained in a molybdenum boat using a conventional arrangement and a high-voltage power supply provided to the evaporation target. The prepared CdS thin films were annealed at 100 °C for 2 hours in a muffle furnace.

## 3. Result and discussion

The electrical and optical properties of prepared thin films were investigated using static electrical and photo-luminous optical systems respectively. The standard methods and formulae were used for the calculation of electrical parameters.

### 3.1 Electrical properties

The electrical properties of prepared CdS thin films were studied using half bridge circuit method. In this method with respective surrounding temperature of the film, the voltage is measure and then converted into the resistance. The DC resistance of the films as a function of temperature was measured using the half-bridge method [12]. The thick film was linked in series with an external load resistor (RL) and a set DC voltage was applied to the circuit. Using a digital multimeter, the output voltage across the RL resistor was measured in order to get the values of the film resistance. A digital temperature display system was utilized to display the operating temperature through the use of a chromel-alumel thermocouple. The temperature coefficient of resistance, activation energy, and resistivity of the prepared thin films were calculated using equations 1, 2, and 3 [12, 13].

$$\rho = \left(\frac{R \times b \times t}{l}\right) ohm - cm \qquad (1)$$

Where, R= Resistance of the film at room temperature, t = thickness of the film, b = breadth of the film, $l$ = length of the film.

$$\Delta E = \frac{\log R}{\log Ro} \times KT \qquad (2)$$

Where,

$\Delta E$ = Activation energy,
R = Resistance at elevated temperature,
$R_0$ = Resistance at room temperature.
K = Boltzmann constant and
T = Absolute temperature.

$$TCR = \frac{1}{R_o}\left(\frac{\Delta R}{\Delta T}\right) \,/^{O}C \qquad (3)$$

Where,
$\Delta R$ = change in resistance between temperature $T_1$ and $T_2$,
$\Delta T$ = temperature difference between $T_1$ and $T_2$ and
$R_o$ = Resistance of the film at room temperature.

Fig. 2 shows the plot of temperature versus resistance of the CdS thin films.

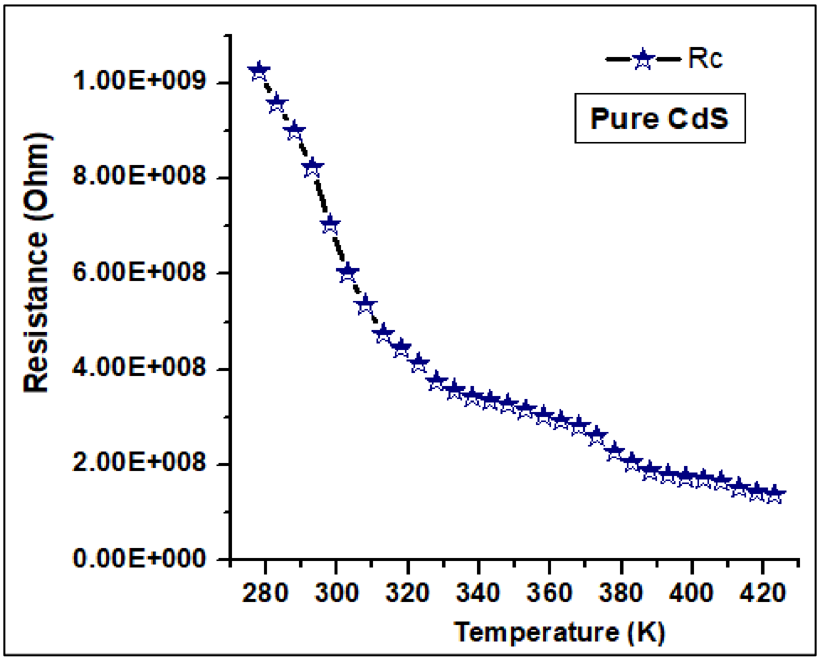


**Figure 2:** Plot of temperature versus resistance of the CdS thin films

It is found from Fig. 2 that the resistance of the film decreases as the surrounding temperature of the film rises. The decline in resistance of the films with increases in surrounding temperature is attributed to the semiconducting nature of the film. The bandgap energy of a semiconductor tends to decrease with an increase in temperature. This reduction in bandgap can result in more carriers being promoted from the valence band to the conduction band, contributing to increased conductivity [12, 13]. The energy needed for charge carriers, such as electrons or holes, to migrate from the valence band to the conduction band and so affect electrical conduction, is known as the activation energy of CdS thin films. This activation energy is related to the temperature dependency of carrier mobility and conductivity in the environment of semiconductors. The activation energy experimentally, one would typically measure the conductivity of the CdS thin film at different temperatures and then analyze the data using the Arrhenius equation [13, 14]. By plotting the natural logarithm of resistance against the reciprocal of temperature as shown in Fig. 3. The summary of estimated electrical parameters of CdS thin films are tabulated in Table 1.

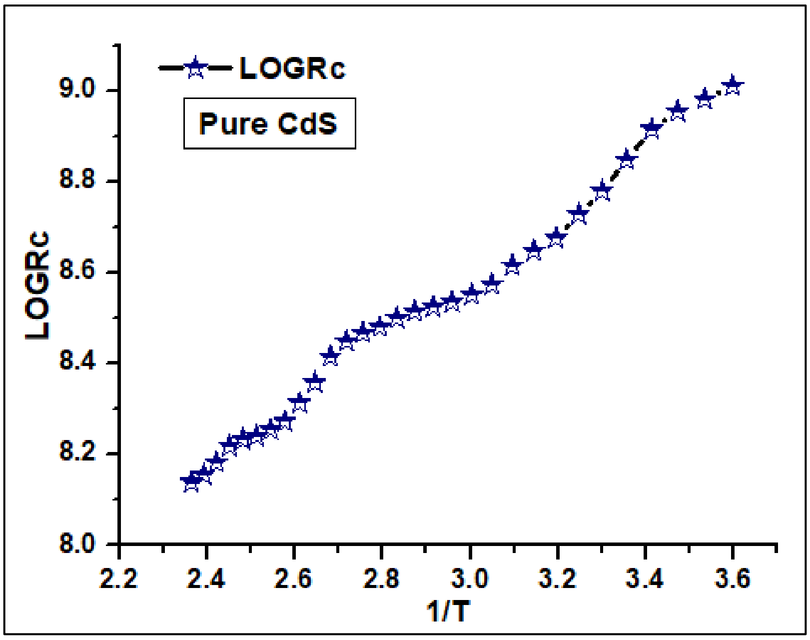


**Figure 3:** Arrhenius plot of the CdS thin films

**Table 1:** Summary of estimated electrical parameters of CdS thin films

| Sample | Thickness (nm) | Resistivity (Ω.cm) | TCR (/°C) | Activation Energy (eV) | |
|---|---|---|---|---|---|
| | | | | HTR | LTR |
| CdS | 72 | 36.881 | -0.00195 | 0.2532 | 0.1808 |

**3.2 Optical properties**

Photoluminescence studies of CdS thin films are valuable for characterizing the material's optical and electronic properties, understanding defect states, and optimizing the fabrication process for various applications such as solar cells, light-emitting diodes (LEDs), and photodetectors. The photoluminescence study of CdS thin films involves investigating the emission of light (photons) by the material when it absorbs photons of higher energy (shorter wavelength), typically through the process of absorption followed by re-emission [15, 16]. This phenomenon provides valuable information about the optical and electronic properties of the CdS thin film. Examining the way the material's electrical characteristics alter in response to light, especially in relation to its behavior as an insulator or semiconductor, is one way to study the optical features of CdS thin films. CdS thin-film photoresponse research may reveal important details about the material's behavior under light and its potential for a range of photovoltaic uses. Furthermore, the findings might further knowledge of its electrical characteristics and prospective applications in modern technology. In this study, we investigated the light-dependent conductance variations of prepared CdS thin-films as a potential optical sensor or photovoltaic device [16, 17]. Fig. 4 illustrate the intensity (light) versus photocurrent plot of CdS thin-films. Photoluminescence study shows the prepared CdS films shows maximum response to blue filter compare to other selected filters.

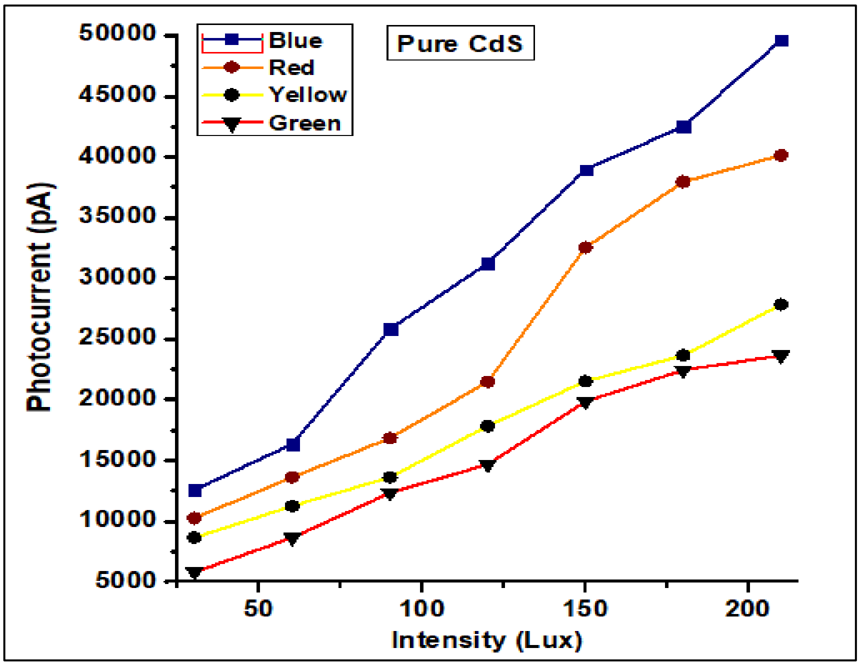


**Figure 4:** Intensity versus photocurrent plot of CdS thin-films

**Conclusions and Future Scope**

1. The thin films of CdS successfully prepared by physical vapour deposition technique.
2. The prepared CdS films shows semiconducting nature.
3. The resistivity was found to be for prepared CdS films is 36.881 Ω.cm
4. The optical properties of prepared CdS films were studied.
5. Photoluminescence study shows the prepared CdS films shows maximum response to blue filter compare to other selected filters.
6. The CdS thin films could be useful for fabrication of photodetectors as well as photovoltaic cells.

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# A NEW VARIETY OF *IPOMOEA TRILOBA* (CONVOLVULACEAE) FROM DECCAN PLATEAU, INDIA

D.K. LONDHE* AND A.S. BHUKTAR[1]

*MVPSamaj's Art, Commerce & Science College, Dindori, Nashik (MH), India*

*Keywords: Ipomoea*; Convolvulaceae; New variety; Maharashtra; India.

**Abstract**

*Ipomoea triloba* L. var. *deccansis* D. K. Londhe & A.S. Bhukatar, var. nov. are described here as a new variety of *Ipomoea triloba* L. (Convolvulaceae) from the Western Ghat of the Deccan plateau, North Maharashtra, India. Observations in the field as well as in cultivation for three years showed that the variety retains its diagnostic characteristics and no intermediate exists. Detailed descriptions and photo plates are provided to facilitate the identification of this new variety.

## Introduction

*Ipomoea* L. is one of the dominant genera in the family Convolvulaceae, popularly known as "Morning Glory". It represents ca. 650 species and is mainly distributed in tropical and warm temperate regions of the world (Mabberley, 2008). The World Flora Online includes ca.3000 scientific names of species rank for this genus of which ca.714 are accepted names (WFO, 2020). Out of 2537, records retrieved in the World Checklist of Selected Plant Families, ca. 670 accepted species names entered for *Ipomoea* (WCSP, 2019). India represented 60 species previously (Santapau and Henry, 1973), but subsequent records of *Ipomoea mombassana* Vatke (Biju *et al*., 1998), *I. parasitica* (Kunth) G. Don (Biju, 2002) and *I. ochracea* (Lindl.) G. Don, *I. tenuipes* Verdc. (Shimpale *et al.,* 2012 and 2014) have increased the number of species to about ca. 65. Taxonomists from Maharashtra state reported about 37 species of *Ipomoea* (Cooke, 1905; Naik, 1998; Almeida, 2001; Shimple *et al.,* 2012, 2014; Undiwade and Bhadane, 2017; Kattee *et al*., 2019).

Authors accidentally came across with an interesting specimen of *Ipomoea* during investigation, at western ghats of Deccan plateau of North Maharashtra, India. The collected specimens were compared with the herbarium (*BAMU, BSI*). We searched through online photographs as well as *Ipomoea* species occurred in regional online flora, and plant list, IPNI, JSTOR portal, monograph of *Ipomoea* (Convolvulaceae) in the New World (Wood *et al.,* 2020.) hence revealed that it resembles with *I. triloba* L. but differ in its morphological traits that turn out it as a new variety.

## Material and Methods

Materials were collected in the months of September to January from 2019-2021 at western edge of Deccan Plateau of Western Ghat North Maharashtra, India. All specimens collected were processed using standard herbarium techniques (Jain and Rao, 1977). The authors have collected and recorded the necessary data regarding habitat, habit, morphological variations, phenology and geographic information such as coordinates of the type localities during the field visits. The comprehensive photography of the morphological characters was taken by using D6000 camera (Nikon, Japan) and CMZ-6 stereomicroscope (Labomed, Japan). The scientific novelty of the

*Corresponding author. E-mail: dhananjaylondhe45@gmail.com

[1]MVPSamaj Arts, Commerce & Science college, Dindori, Nashik (MH) India.

specimens was confirmed by a critical survey of the literature (Hooker, 1882; Cooke, 1905; Naik, 1998; Almeida, 2001; Singh *et al.*, 2001) and comparing with specimens available at BSI, BAMU and images of specimens available in the virtual database of JSTOR (2020), *Ipomoea* species occurred in regional online flora, and plant list, IPNI, monograph of *Ipomoea* (Convolvulaceae) in the New World (Wood *et al.*, 2020.) Edinburgh herbarium (https://data.rbge.org.uk/search/herbarium/) and Kew Herbarium (http:// apps.kew.org/herbcat/ navigator.do).

## Taxonomic treatment

***Ipomoea triloba* L. var. *Deccansis*** D. K. Londhe & A. S. Bhukatar var. nov. **(Fig. 1)**

The new variety is morphologically allied to *Ipomoea triloba* L. but distinct by having tap root with adventitious roots, completely white petals, completely green sepals, stem, petiole and pedicle, dimorphic leaves, bract persistent, white stamens, hairy style, globose stigma, glabrous ovary, greenish and glabrous capsule, persistent bract, marginal pilous seeds, longer corolla, peduncles longer than petiole.

*Type:* INDIA, Maharashtra, Nasik, Dindori 73°48′25.92″E, 20°12′12.02″N elevation ca. 640m, November 2019, D.K. Londhe. 3297 (Holotype CAL; Isotype BSI, Pune).

Annual climber, ca. 8 m long. Tap root. Stem cylindrical, wiry, green, pubescent, rooted at nodes and internodes in contact with soil, latex milky. Leaves simple, ovate to obovate, 5-8 x 2-7 cm, glabrous above, pubescent beneath, 3-5 lobed, deeply notched, lateral lobes directed backwardly, margin entire, minutely hairy; stipule small, caduceus, pubescent; petiole 2-3 cm, glabrous or sparsely pubescent. Inflorescence axillary umbel cyme, 1-7 flowered in short lax; peduncle up to 18 cm, longer than petiole, swollen at apex. Flowers bracteate, pedicellate; pedicel 0.3-0.5 cm, bracts ovate, persistent, pubescent, ca. 6 mm long; bracteole 0.3-0.4 cm linear, green. Sepals 5, unequal, 0.7-1.2 cm long, 3-7 mm broad, greenish at apex elliptic ovate to lanceolate, throughout green, usually glabrous, faintly veined; outer two sparsely hairy at lobe**.** Petals 5, gamopetalous, funnel shaped, completely white, ca. 2.5-3 x 1.8-2.5 cm, 5-lobed, mucronate, tube 1-1.8 cm. Stamen 5, 0.8-1.5 cm, unequal filaments, hairy at base, included, dithecous, white. Stigma globose, white; style 1-1.3 cm long, usually glabrous. Style 0.8-1.3 occasionally hairy. Ovary 1.3-1.5 cm, glabrous**.** Capsule greenish, grey after dry, glabrous, ca. 1 x 1 cm, dehisces in four halves. Seeds brownish black, triquetrous, marginally pilous with brown hairs.

*Flowering & Fruiting:* Flowering from September to January and fruiting from December to Feburary

*Habitat:* Common along wet shady rocky slopes in association with *Indigofera tinctoria* L., *Alysicarpus heyneanus* Wight & Arn, *Crotalaria pallida* var. *obovata* (G. Don) Polhill, *Lantana camara* L., *Achyranthes aspera* L.

*Etymology:* The variety epithet 'Deccansis' refer collected from Western Ghats of Deccan plataue North Maharashtra, India.

*Distribution:* **INDIA**, (Maharashtra; Nasik district; Dindori) Rare.

## Conservation status:

*Ipomoea triloba* L. Var. deccansis is only reported from single locality from Deccan plateau. It grows in open wet shady rocky slopes. No detailed data is available on the distribution and population of this variety, hence assessed here as Data Deficient (DD) as per the guidelines of IUCN (2019).

*Additional specimens examined:* **BAMU:** Western Ghats, Talegoan tank 22 Nov. 1975 *V. N. Naik* 2828 ; Aurangabad, 19 March 1978, *V. N. Pardeshi* 4201.

*BSI Pune:* Naygaon- Thane, 1968, *Billore* 133774; Ramteldhari Tank- Chandrapur, 1972, *Kulkarni* 133991.

*Note:* The new variety is closely allied to *Ipomoea triloba* L. but differs by its tap root with adventitious roots, completely white corolla, white stamens, completely green sepals, stem, petiole, pedicle, bract persistent, capitate stigma and sparsely hairy style with a glabrous ovary, greenish and glabrous capsule, seed marginally pilous with brown hairs.

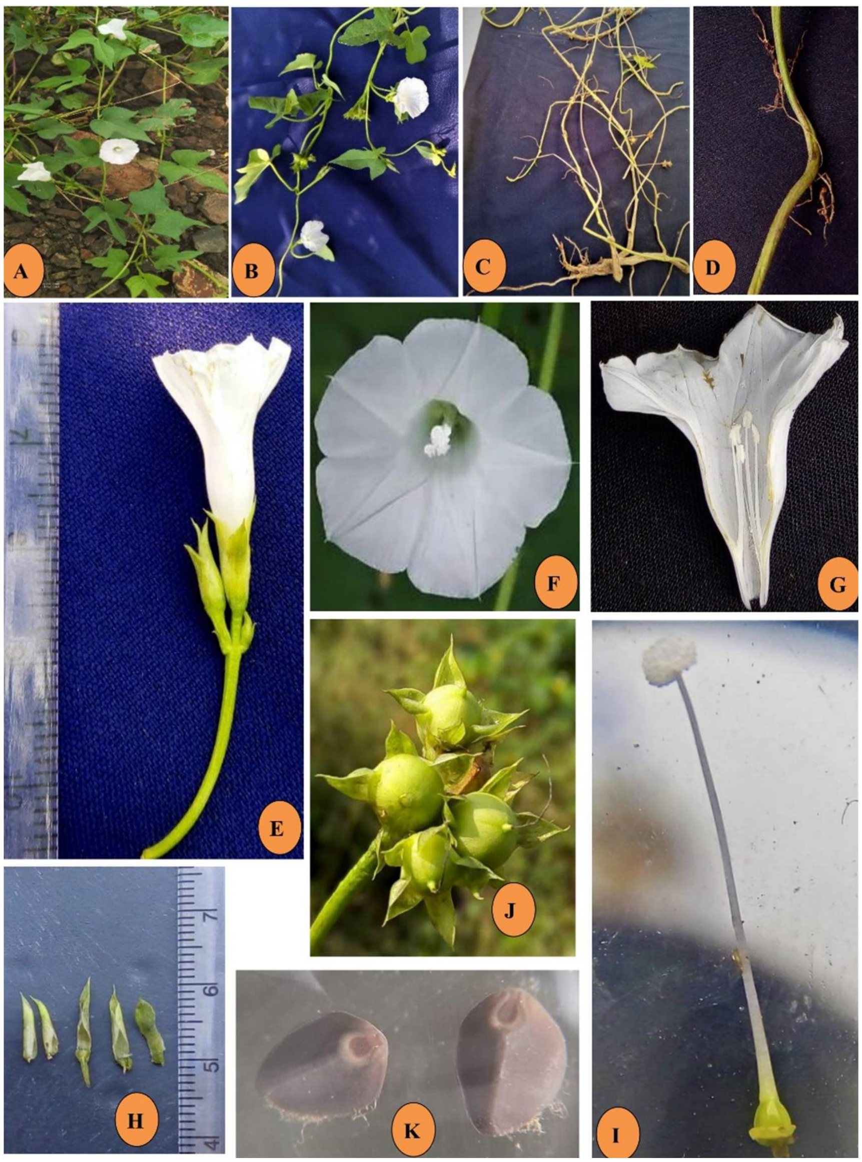


Fig. 1. *Ipomoea triloba* L. var. deccansis D.K. Londhe & A.S. Bhukatar var. nov. A. Habit, b. Twing, C. Tap root, D. Adventatious root, E. Flower with npedicle and calyx, F. Corolla, G. Open split corolla with white stamens, H. Glabrous sepals, I Pistil, J. Glabrous capsule, K. Seed.

**Table 1. Comparative characters of *Ipomoea triloba* L. var. deccansis D.K. Londhe & A.S. Bhukatar var. nov. with allied species.**

| Characters | *I. triloba* L. | *I. triloba* var. *deccansis* var. nov. |
|---|---|---|
| Tap root | Present | Present |
| Stem color | Purple | Greenish |
| Adventitious root | Absent | Present |
| Leaf lobes | 3-5, side lobes blunt or pointed and forwardly directed | 3-7, side lobes pointed backwardly directed |
| Inflorescence | Dense cyme (5-7 flowered) | Lax Cyme (2-7 flowered) |
| Bract | Caducous | Persistent |
| Sepals tip | Pink tip | Greenish |
| Corolla color and size | Red(1.5 x 1.2 cm) | White (2.5-3 x 1.8-2.5 cm) |
| Anther | Pink | White |
| Stigma | 2-lobed | 1-lobed |
| Style | Glabrous | Hairy |
| Ovary | Densely pubescent | Glabrous |
| Capsule | Pubescent purple | Glabrous greenish |
| Seed | Glabrous | Pilous with hairs |

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# Study of Fish Markets in Dindori Tehsil of Nashik District, Maharashtra

**DH Dudhmal*, PS Kad, DP Khairnar, CK Rajdev**
Department of Zoology, MVP Samaj's Arts, Commerce and Science College Dindori (Nashik), Maharashtra, India

**ABSTRACT**

Fish serve as an important delicacy throughout the world. In Maharashtra as well, fishes and other aquatic foods are preferred over other forms of meat. There is a great variety in terms of available fishes and the prices at which they are sold in different fish markets in Maharashtra. The current study was carried out in Dindori tehsil of Nashik district covering two major markets viz Dindori and Vani fish markets to answer the questions related to diversity of fishes, selling rates and consumer behaviours like preference and days of purchasing. The data was collected through questionnaire from December 2023 to February 2024. It was found that fish market system was observed which included various elements forming a chain. It was also found that Rohu and Catla were the most preferred Indian major carps in the market while eel and prawns were least available. The consumer behaviour is attributed to the size of the fish, availability of the fish and religious days and festivals.

**Keyword:** Fresh market, fresh water fish, Dindori, Vani, Nashik.

## INTRODUCTION

Fish has been consumed by Indians from centuries. India's fish consumption dates back to 2500 BCE (1) With a species count of over 33000, fishes serve as a major source of nutrients like proteins, oil and omega 3 fatty acids, playing vital role in maintaining ecological balance and also supporting fishery industries across the world by strengthening economy (2). India is the third largest fish producer and second largest producer in aquaculture in the world and contributes 8% to the global fish production (3,4) . Fisheries sector contributes 1.1% to the Indian GDP and 6.72% to the agricultural GDP (5, 6). As the people are becoming more health conscious, the demand of a protein rich food has increased and fishes are the best source to fulfil this requirement that resulted in rise in fish consumption. It is significantly giving growth to the fish market (3). As far as Indian states are concerned, Andhra Pradesh stands first in fish production ahead of West Bengal and Gujrat (7,8) 72.1% of the total population of the country includes fish into their diet and among the Indian states, Tripura stood first in having the highest population eating fish while Haryana the least (9).

Fishes are aquatic vertebrates which are cold blooded and having good source of proteins, vitamins and minerals. They also play a vital role in maintaining the ecological balance. The fishes also support highly benefitting industry as well. Fish market can be defined as a place where selling and buying of fish and fish products take place by fishermen, wholesalers, retailers, consumers. Crawford fish market is the biggest fish

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# An Overview of Poultry industry in and after Covid-19 in India

**D Tigote[1], D H Dudhmal[2*], R S Babare[3], S N Padghane[4]**
[1]Sanjeevanee Mahavidyalay, Chapoli (Latur)
[2]Department of Zoology, MVP Samaj's ACS College, Dindori (Nashik), [3]Late Nitin College, Pathri (Parbhani)
[4]MSP Arts, Science and KPT Commerce College, Manora (Washim) *Corresponding author
email:dilipdudhmal@gmail.com

**ABSTRACT**

Covid-19 pandemic after its first outbreak in Wuhan, China in the late 2019, became a threat to the entire world affecting all sectors associated with human economy and health. The effects were more severe than moderate. Like all other sectors, poultry industry was badly hit by the flood called covid-19. This industry was destroyed due to the uncontrolled rumors spread across social media platforms in the early period of the pandemic. It was speculated that consumption of poultry, eggs and meat brings corona virus infection. This misinformation brought over 70% loss in egg market but the poultry industry was back on track after the authorities world over like World Health Organization (WHO) clarified that this outbreak is not spread though chicken or any other non vegetarian food consumption. This is an overview which documents how the poultry industry in the country was affected in the initial period of the outbreak and what were the factors which turned out to be boost for the industry.

**Introduction:**

The covid-19 outbreak has affected more than 200 countries across the world. There have been 540,923,532 confirmed cases and 6,325,785 deaths across the world [1]. India is also one the most affected countries in the world. There are a total of 4,34,07,046 confirmed cases while there are 5,25020 deaths so far [1]. Poultry industry is a fast growing sector in India. With an annual production increasing by 8-10% per year, India now stands at the third position after China and United States in egg production and as far as the broiler production is concerned, India is ranked fourth in the world after China, Brazil and United States [2]. There are several factors which helped India to reach to this position like increasing population, increase in per capita income and cheap prices. In just 40 years, India's poultry industry has transformed into a major commercial activity. But, despite being placed at the fifth rank worldwide, consumption of poultry products like eggs and poultry meat is considerably low [3]. It is found that in rural areas, it is least preferred food commodity compared to the urban areas. It has recorded as a continuous increase over years. In the year 2020, the consumption rate was 3.9 million metric tons [4, 5]. There were floods of misinformation ever since the outbreak all across the world. People feared that the virus spreads from an animal especially from poultry and meat and as a result of it; people started avoiding non-vegetarian food items [6, 7]. This belief directly affected poultry industry in India. The demand to chicken and other non-vegetarian food items decreased as low as by 80%. Chicken was available for INR 50-60/kg. Some poultry farmers were selling the chicken for free while others preferred

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# Study of Fish Markets in Dindori Tehsil of Nashik District, Maharashtra

**DH Dudhmal*, PS Kad, DP Khairnar, CK Rajdev**

Department of Zoology, MVP Samaj's Arts, Commerce and Science College Dindori (Nashik), Maharashtra, India

**ABSTRACT**

Fish serve as an important delicacy throughout the world. In Maharashtra as well, fishes and other aquatic foods are preferred over other forms of meat. There is a great variety in terms of available fishes and the prices at which they are sold in different fish markets in Maharashtra. The current study was carried out in Dindori tehsil of Nashik district covering two major markets viz Dindori and Vani fish markets to answer the questions related to diversity of fishes, selling rates and consumer behaviours like preference and days of purchasing. The data was collected through questionnaire from December 2023 to February 2024. It was found that fish market system was observed which included various elements forming a chain. It was also found that Rohu and Catla were the most preferred Indian major carps in the market while eel and prawns were least available. The consumer behaviour is attributed to the size of the fish, availability of the fish and religious days and festivals.

**Keyword:** Fresh market, fresh water fish, Dindori, Vani, Nashik.

## INTRODUCTION

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