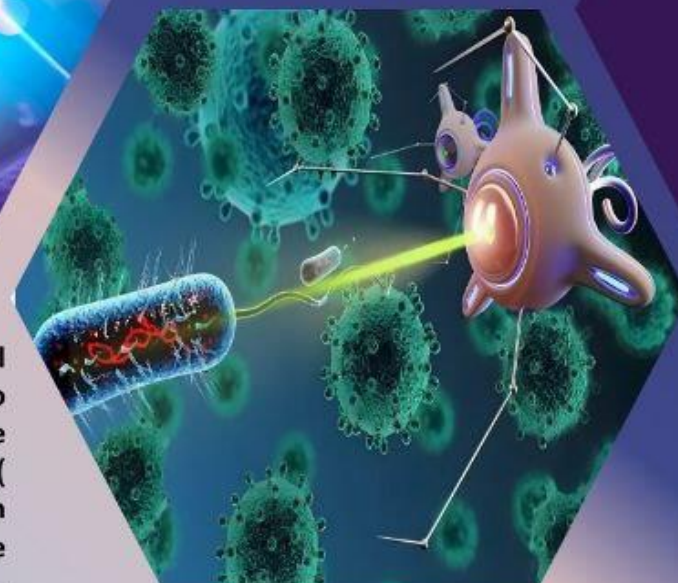
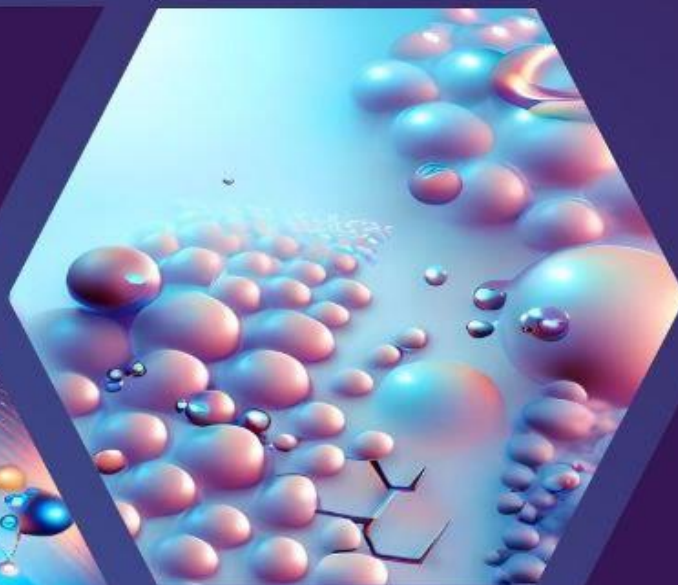
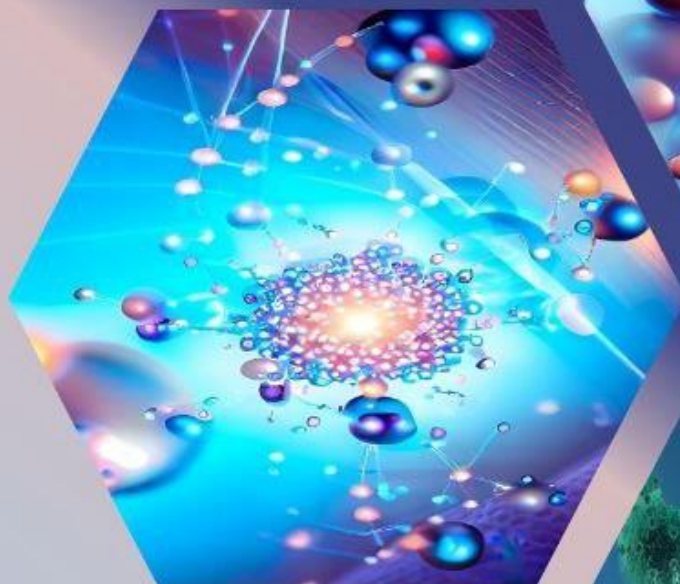




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The exceptional properties of two-dimensional atomic crystal materials can be attributed to their distinctive structural characteristics. In the other side, the chemistry of organotin(IV) complexes has received a lot of attention in recent decades because of their wide applicability in numerous fields. Multicomponent analysis works to determine the mutual quantitative and qualitative arrangement using the spectra, and because their ranges have not been resolved yet, it is possible to use the first or highest derivatives according to the wavelengths, and this is evidence that the derivation of the absorption spectra increases the selectivity. On the other hand, Accidental oil spills stemming from incidents involving the dispersion of petroleum substances, often originating from maritime vessel mishaps, have been recognized as a recurring environmental challenge, predominantly affecting marine environments.

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Progress of preparation and Application of two-dimensional Transition Metal -Dichalcogenides – 2D-TMDs

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ABSTRACT

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The exceptional properties of two-dimensional atomic crystal materials can be attributed to their distinctive structural characteristics. Compared to graphene, Two-Dimensional Transition Metal Dichalcogenides (2D-TMDs) exhibit diverse sizes and adjustable band gaps, making them appropriate for utilization in the field of microelectronics. The field of optoelectronic devices displays significant potential for utilization across diverse domains. This article comprehensively analyses the methodologies employed in manufacturing 2D-TMDs materials, specifically «top-down" and "bottom-up" techniques. The research additionally provides a comparative evaluation of frequently utilized techniques. Furthermore, a synopsis of their advantages and disadvantages is presented. Concurrently, tackling the practical obstacles linked to the chemical vapor deposition methodology concerning forthcoming wafer-level 2D-TMDs devices is crucial.

Keywords: 2D-TMDs, top-down approach, Bottom-up growth model, Exfoliation, chemical/Physical vapor deposition PVD/CVD.

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1. INTRODUCTION

Their Interest in 2D-atomic crystals has recently increased, particularly after the discovery of graphene. These materials have captured the attention of scientists due to their layered structure and unique physical and chemical properties [1]. The layers in these materials are held together by solid ionic or covalent bonds and are connected through weak van der Waals (vdW) forces. This structural arrangement allows for the rapid production of monolayer materials through micromechanical Exfoliation and ion intercalation [2]. Graphene, in particular, has garnered significant attention for its exceptional electrical, optical, and chemical characteristics. However, its lack of a bandgap limits its application in electronics and optoelectronics, prompting researchers to explore alternative 2D materials [3]. Transition metal sulfur compounds, specifically the family of TMDs such as WSe₂ and MoS₂, have emerged as promising candidates due to their tunable bandgap. TMDs share similarities with graphene in their layered structure, with an MX₂ composition [4]. The electrical properties of TMDs span a wide range, including semiconductors, semi-metals, and superconductors [5], as shown in Table 1 [6]. The bandgap of these materials can be influenced by the width of the TMD layers, which can be controlled through variations in stresses and stacking methods [7]. These characteristics make TMDs highly adaptable for future device

applications. However, several challenges must be addressed before TMDs can be effectively utilized in practical scenarios.

Understanding the fundamental physical properties of TMDs is an ongoing area of research. Further studies are needed to optimize the characteristics of electronic devices and align them with specific application requirements. For example, the carrier mobility of TMDs is lower than that of graphene, which limits the drive capability and operating speed of TMD-based devices [8]. Additionally, the full potential of TMDs in optoelectronic devices has yet to be fully explored. There is a need to investigate energy band variations and the optoelectronic characteristics of novel heterogeneous and composite materials. Successful implementation of TMDs depends on the development of equipment capable of producing controllable materials over large areas and technological advancements. Controllable preparation of TMDs with a specific number of layers is crucial for understanding their energy band structure. Currently, there are two main approaches for producing Monolayer (ML) or few-layer (FL) TMDs: the "top-down" and "bottom-up" methods. The "top-down" techniques include micro-mechanical stripping, ion intercalation stripping, and liquid-phase ultrasonic lift-off methods. Furthermore, the "bottom-up" approach involves CVD and physical

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vapor deposition, which offer spatial uniformity and the potential for large-area thin film production with controlled thickness. This article explores these preparation methods.

Table 1. Electronic characteristics of different 2D-TMDs

Group number	Transition metal element M	Chalcogen element X	physical properties
IV	Zr, Hf, Ti		Diamagnetic; Semiconductor (S-C) ($E_g=0.19\sim 1.99$ eV)
V	Ta, Nb, V		Narrowband metal /semimetal ($\rho\sim 10^{-4}$ Ω cm); superconductor; cis, antiferromagnetic / diamagnetic
VI	W, Mo	S, Se, Te	Se, S: semiconductors ($E_g\sim 0.99$ eV). Te: semimetals ($\rho\sim 10^{-3}$ Ω cm); diamagnetic
VII	Re, Tc		small gap semiconductor; diamagnetic
X	Pd, Pt		Se, S: S-C ($E_g=0.4$ eV), diamagnetic; Te metals, paramagnetic; PdTe ₂ superconductor

and provides an overview of recent advancements in 2D-TMDs preparation technology and their utilization in electronic devices.

2. PREPARATION OF 2D-TMDS

According to the different ways of preparing 2D-TMDs thin slices, the methods of preparation can be categorized into two distinct classifications: one is to peel off 2D-TMDs thin cuts through the crystal block of TMDs, which is referred to as the "top-down" process; the other is to obtain TMDs crystals or films with an atomic layer thickness through chemical reactions, which is referred to as the "down-top" method.

2.1. The "top-down" approach

The "top-down" approach effectively reduces the vdW force between the layers of material. In the case of 2D-TMDs, whether single-layered or multi-layered, the layers are extracted from the bulk material through an Exfoliation process. This approach offers several advantages, including its simplicity and user-friendliness. Various conventional techniques are used for top-down preparation, such as [8]:

2.1.1. Micromechanical Exfoliation Method

The micromechanical stripping method is a method to separate thin slices from layered bulk materials by applying mechanical force. This method is a traditional method for preparing 2d material sheets. There have been early reports on preparing multi-layer MoS₂ by tape [9] and stripping multi-layer graphene .In 2004, Novoselov et al. [1] Obtained monolayers of graphene by repeatedly thinning graphite sheets with adhesive tape using the principle of micromechanical stripping and then using the same method to obtain single-layer h-BN, MoS₂, NbSe₂, etc. In recent micromechanical Exfoliation, method is shown in Figure. 1(a). Firstly, a layer of fragile material is torn off from the block material by conventional Scotch tape or non-

residual low-viscosity tape (Nitto). The tape is repeatedly folded and glued in half. When the material on the tape is thinned to a certain extent, the tape has adhered to a clean SiO₂/Si substrate. After removing the tape, thin slices of different thicknesses will be left on the bottom. Single or multi-layer thin slices can be easily identified. Thin slices can be differentiated based on color when viewed under an optical microscope, as shown in Figure. 1(b). In 2020 Huang et al. [10] successfully prepared a large-area, high-quality, pollution-free single layer. The study employed a single-step, universal mechanical Exfoliation technique assisted by Au to isolate monolayers of years; micro-mechanical stripping has been widely used to prepare ML graphene, H-BN, TMDs, and other graphene-like monolayers. The choice of substrate type also has a substantial effect. The double-layer structure of thermal oxidized SiO₂(300 nm) on Si substrate is the most predominant type of substrate for 2D materials. This substrate can enhance the optical interference contrast of 2D-atomic crystal films of different thicknesses, and it is easy to judge the number of layers of 2D materials. At the same time, due to the excellent conductivity of doped Si, it is also suitable for fabricating back-gated field-effect transistors to reduce the difficulty of the device process.

The general process of preparing 2D-TMDs by the various types measuring 40 μ m. The isolated monolayers included elemental 2D crystals, metal-dichalcogenides, metal monochalcogenides (such as SnS), metal trichlorides (such as RuCl₃), black arsenic, black phosphorus, superconductors, and magnetic compounds (such as Fe₃GeTe₂). The majority of the specimens are of millimeter-scale dimensions and exhibit superior quality, as depicted in Figure 1(c-d). The measurements depicted in Figure 1(e-g) pertain to transfer-free electron microscopy, electrical transport, and photon spectroscopies.

The micromechanical method is simple and has a low cost. The single or multi-layer 2D-TMDs flakes obtained have a good crystal structure and fewer defects and can be stably preserved in the air for a long time. It is suitable for the characterization of some substrates.

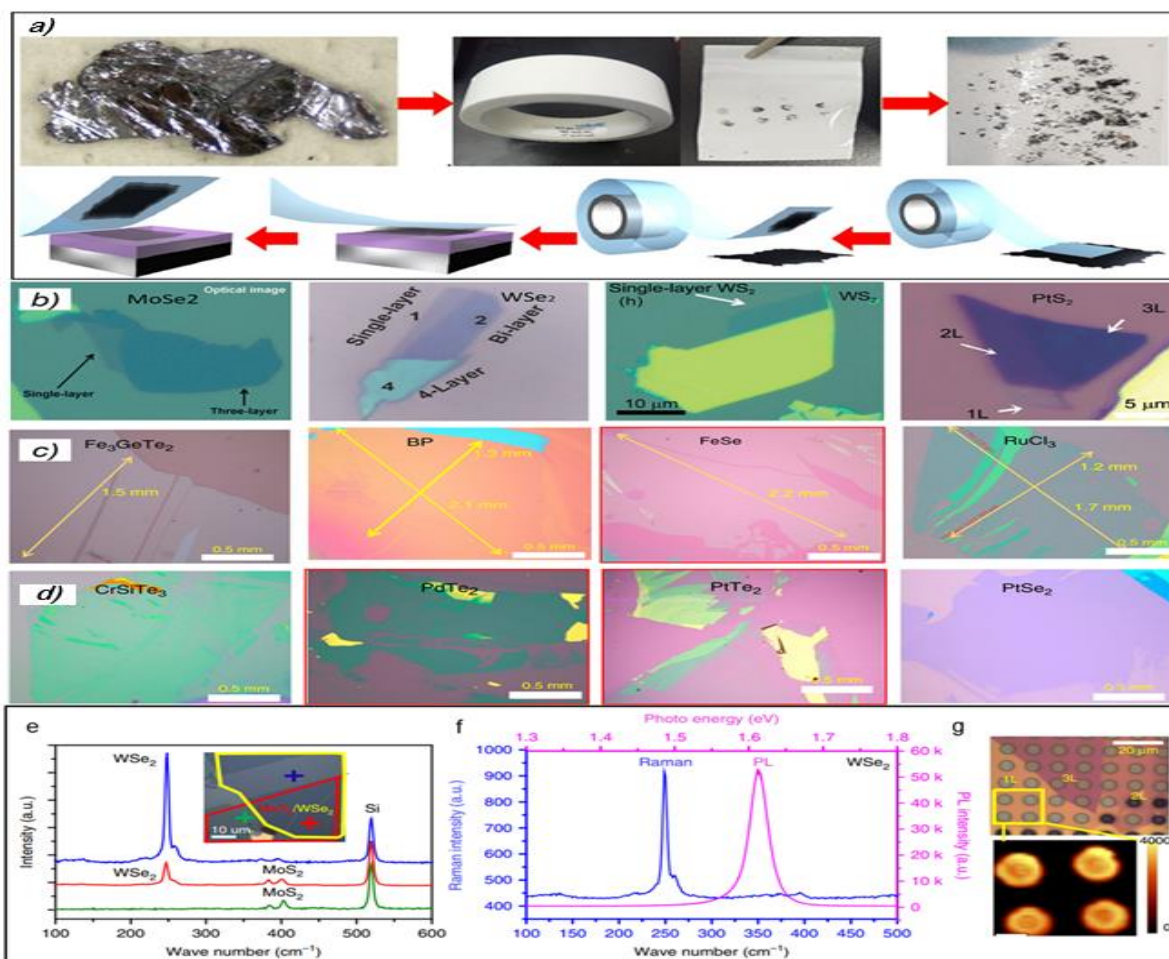


Figure 1. Illustrates the process of mechanical Exfoliation. (a) Exfoliation process [11] (d) MoSe₂, WSe₂, WS₂ [12], and PtSe₂ [13] (c) Fe₃GeTe₂, BP, FeSe, and RuCl₃, (d) CrSiTe₃, PtTe₂, PdTe₂, PtSe₂ respectively [10]. (e) Raman spectra of a MoS₂/WSe₂ heterostructure Inset OM image. (f) Raman and PL spectra of ML-WSe₂, (g) OM image of WSe₂ at different layers, inset a PL Intensity map image matching the designated area [10].

and the fabrication of single devices. Compared with molecular beam epitaxy (MBE), micromechanical stripping provides excellent convenience for scientific research. Many types of research on single or multi-layer 2D-TMDs flakes prepared by the micromechanical stripping method have been reported, such as low-power electronic devices [14] Optoelectronic devices [15], Superconductivity [16], and Valley Electronics Science [17], etc. Nevertheless, this technique poses difficulties in regulating the dimensions of the 2D-TMDs sheet, including its area, thickness, and shape, while exhibiting low repeatability and yield.

2.1.2. Lithium-ion intercalation Exfoliation method

Although micromechanical stripping can quickly obtain 2D TMDs with near-perfect atomic thickness in the crystal structure, its low yield and poor repeatability limit its practical application. In 1975, Whittingham *et al.* [12] first reported the preparation of 2D-TMDs by lithium-ion intercalation. In 1986, Joensen *et al.* [18] improved the method for obtaining a monolayer of MoS₂ using lithium-ion intercalation. This approach has been applied in the growth of 2D materials. The steps involve preparing MoS₂ powder, mixing it with n-butyl lithium in an n-hexane solution, and subjecting it to a three-day reaction under an inert gas environment at 100°C Figure 2(a).

The resulting stripped intercalation is then treated with deionized water, ultrasound, and filtration to obtain MoS₂ flakes Figure 2(d). Limitations include the lengthy process time (over 1 day), the need for inert gas protection due to the explosive nature of lithium metal, and the high cost of lithium, which restricts its application.

In 2011, Zeng *et al.* [19] devised an electrochemical ion intercalation stripping technique that is more efficient and manageable in producing flakes of graphene, h-BN, and different 2D-TMDs. The procedure in question is depicted in Figure 2(b). The cathode in a lithium-ion battery device typically comprises bulk-TMDs, while the anode is typically composed of lithium foil. After discharge (lithium ions are inserted between the layers), they put the intercalation material (such as Li_xMoS₂) Ultrasound in water or ethanol. Lithium generates hydrogen in water or ethanol. The hydrogen separates adjacent MoS₂ layers, and finally, a fully dispersed MoS₂ sheet is obtained, as shown in Figure 2(c). In general chemistry, the lithium-ion intercalation stripping method usually requires a higher temperature and a longer reaction time.

In contrast, the electrochemical ion intercalation stripping method can be completed in only a few hours at room temperature, and the discharge curve can serve as a means of control through monitoring.

The insertion process and quantity of ions significantly improve the efficiency. However, the preparation conditions are strict, and the

removal of lithium ions can easily lead to the aggregation of 2D-TMDs.

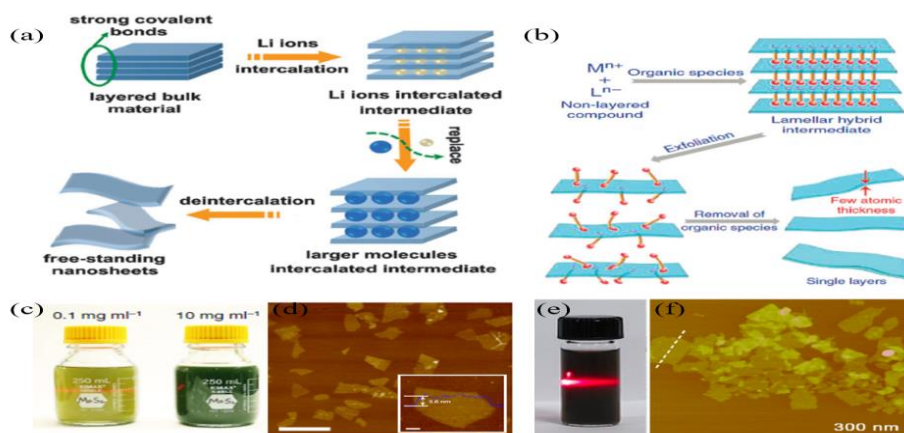


Figure 2. The 2D-TMDs materials that have undergone Exfoliation and lithium intercalation. (a) A diagrammatic representation of the process of lithium intercalation [20]. (b) a schematic installation of the Exfoliation strategy utilizing lamellar hybrid intermediates [21]. (c) dispersal of exfoliated MoS₂ nanosheets in isopropanol at varying concentrations. (d) AFM image depicts several nanosheets of MoS₂ exhibiting a limited range of thickness. (e) A suspension of MoS₂ nanosheets. (f) AFM image of ML-MoS₂ [22].

2. 1. 3. Liquid phase ultrasonic Exfoliation method

The liquid-phase ultrasonic method disperses bulk powder of 2D materials in water or organic solvent and utilizes ultrasonic waves to peel surface flakes, as shown in Figure 3(a). This method offers a large-scale preparation approach for 2D-TMDs thin slices without the inconvenience and hazards of the lithium-ion intercalation method. Flakes prepared through liquid-phase ultrasonic Exfoliation are typically several hundred nanometers in size and exhibit stable dispersion due to molecular adsorption and repulsion in the solution

[23]. Coleman et al. [24] successfully prepare MoS₂, MoSe₂, MoSb₂, ...etc. Flakes using a liquid-phase exfoliation method. Different solvents were tested for improving the exfoliation efficiency, with N-methyl pyrrolidone (NMP), mixed water, and ethanol solutions showing positive results for dispersing MoS₂ flakes. Even though the liquid-phase ultrasonic exfoliation method is simple and suitable for mass production, its exfoliation efficiency is generally not high. The resulting flake solution has a low concentration and a low content of monolayer flakes, and achieving optimal results depends on precise control of ultrasonic conditions.

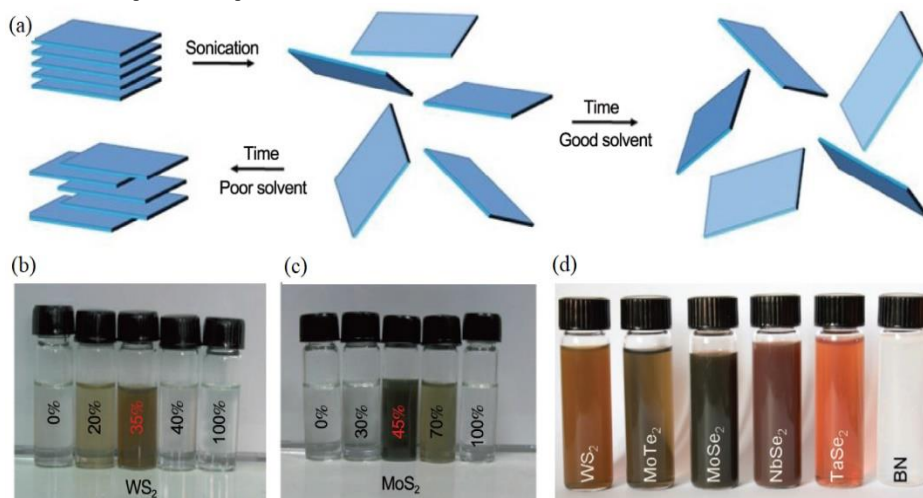


Figure 3. Liquid phase sonication-prepared 2D TMDs materials. (a) A schematic explanation of the liquid phase sonication Exfoliation process for 2D TMD preparation [24]. WS₂ (b) and MoS₂ [25] (c) dispersions in different ethanol-water combinations, respectively, are shown in pictures [26] (d) A photo of NbSe₂, TaSe₂, MoTe₂, MoSe₂, WS₂, and BN dispersions that have been sodium cholate serves to stabilize it in water [27].

2. 1. 4. Laser thermal ablation and thermal annealing

Laser thermal ablation uses the method of laser burning to thin multi-layer, 2D materials. By controlling the wavelength and power of the

laser, 2D materials with different thicknesses can be obtained. In 2012, Castellanos-Gomez et al. [28] used to laser the thermal ablation method to obtain ML-MoS₂, as shown in Figure 4(a)-(c). Its optical and electrical properties are similar to the ML-MoS₂ obtained by the micromechanical Exfoliation method. The laser thermal ablation

procedure has controlled the thickness, area, and the 2D-material sheet's form while ensuring the crystal quality of the single-layer material. However, the cost of the laser is expensive, so the method of laser thermal ablation cannot be applied to large-scale industrial production.

The thermal annealing method can also continuously thin the multi-layer 2D-material sheet to a single layer. In 2013, Lu et al. [29] at 650°C, the argon pressure is 1.33×10^3 Pa, which is a quartz tube of 5 (cm³/min) in this type of furnace, multiple layers of MoS₂ sheets can be thinned layer by layer, as illustrated in Figure 4(d)~(i), at a rate of about 1L/h (Layers/ hour), this method is not yet mature, and it is not strictly following the layer-by-layer method to thin. It is not easy to Get an isotropic surface.

2. 2. "Bottom-up" growth model

The "top-down" 2D-material preparation mode, developed over the past decade, is a mature laboratory method with limitations such as small preparation size, lack of repeatability, and low yield, making it unsuitable for large-scale synthesis. However, the "bottom-up" growth

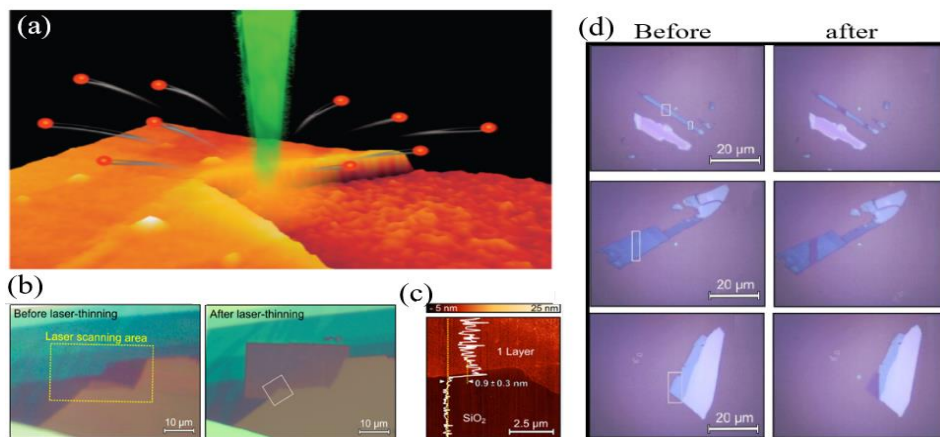


Figure 4. The process of producing MoS₂ flake through thermal ablation via laser-thinning. (a) The diagram depicts the process of laser ablation utilized to thin MoS₂. (b) OM images of FL-MoS₂ flakes growth on SiO₂/Si. (c) OM image of scanning a laser solitary MoS₂ nanosheet (d) annealing for varying durations, specifically 2 h, 4 h, and 7 h, respectively [32].

In recent years, breakthroughs and progress have also been made with the CVD growth of TMDs. Research results have shown that the CVD method can prepare a single-layer continuous 2D-TMDs film with a wafer-level size, and its mobility can be compared with the micromechanical Exfoliation method. The thin film obtained in the "lower" growth mode is quiet [33]. Generally speaking, commonly used CVD thin film deposition techniques can be divided into three types: (1) Thermal vapor chalcogenization (TVC), such as Figure 5(a), (b), the source material compound or an elemental film containing the target component is first deposited on the substrate. Then halogenation is performed in the hot vapor environment. (2) Thermal vapor deposition (TVD), as shown in Figure 5(c), that is, High-temperature heating, makes the precursor source sublime into a gaseous state and flow with carrier gas. Finally, a direct chemical reaction occurs on the target substrate to grow 2D-TMDs films [34]. (3) CVD growth of 2D-TMDs films with a gas source, As shown in Figure 5(d), the reaction source materials are all gas-phase sources. Furthermore, thereaction chamber, with accurate regulation of both concentration and velocity of the endogenous gaseous source

pattern, particularly through CVD, offers advantages such as low cost, large synthesis size, and good quality. This article combines the latest research findings and focuses on the CVD method for synthesizing 2D-TMDs.

CVD involves a chemical reaction between a substance or compound containing 2D-material components and a substrate, resulting in thin film growth. It offers simplicity, low cost, and easy parameter control. For elemental 2D materials like black phosphorus, graphene, catalytic substrates, or templates are selected based on binary phase diagrams, and reactant concentration and temperature are adjusted for material growth. TheCVD growth of monolayer graphene has been successful, producing large, high-quality, uniform films. When grown on metallic nickel (Ni) or copper (Cu) surfaces, it has been able to grow large areas, high quality, uniform, and continuous graphene film [30]. However, the growth of two-component 2D-atomic crystals like 2D-TMDs lacks the self-limiting characteristics of graphene, making it challenging to replicate the same growth method. Controlling growth rates in horizontal and vertical directions and the proportion between them is crucial for achieving the desired grain size, film thickness, and uniformity in TMDs films [31].

material, can synthesize a high-quality, large-scale continuous 2D film on the targeted substrate with a good crystallization condition.

Still, the persistent challenge remains in producing films composed of MDs that demonstrate exceptional quality on a large scale through the CVD technique. To achieve a highly selective growth of ML/BL-WSe₂ single crystals (>500 μm), it is recommended to introduce a pre-annealing step. This step will help in tuning the composition and volatilization rate of the solid precursor, stabilizing the vapor supply, and achieving highly uniform nucleation and growth. This will ensure precise control of the layer number, as shown in Figure 5. (e), (f).

2. 2. 1. Hot steam halogenation

The preparation method of TVC 2D materials mainly includes a two-step process (Fig 5 (a), (b)): 1STstep is to deposit a compound or elemental film layer containing transition metal components on the target substrate. The 2nd step is to place the deposited film in a chalcogen vapor environment (such as S or Se vapor), and then heat

it to a preset temperature for halogenation. The TVC synthesis method can be subdivided into two kinds, whether the deposited source film is a compound or a simple substance. One is the direct halogenation of transition metals. Take MoS₂ as an example. That is a first-deposit nanoscale on the target substrate. The Mo metal film is then placed in a sulfur atmosphere at a high temperature to synthesize MoS₂. The following formula can briefly summarize the reaction principle:



M is a transition metal element, and X is a chalcogen element.

Another TVC method is chalcogenide transition metal precursors (metal oxides, sulfides, etc.). Taking MoO₃ as an example [35]. First,

we use an appropriate method (thermal evaporation, magnetron sputtering, etc.) on the target substrate. (Thermal evaporation, ALD, etc.) deposit a layer of MoO₃ (or other transition metal precursors such as MoS₂) that is uniform, easy to chalcogenide, put it in a sulfur atmosphere at a certain temperature for chemical reaction, and finally form MoS₂ film. In the halogenation process, the conversion of precursors can be directly formed by chemical reactions to form TMDs [36]; it can also be a two-step thermal reaction. Still taking MoO₃ as an example, MoO₃ is first reduced in a high-temperature reducing environment. It is converted to MoO₂ and then undergoes a halogenation response to form MoS₂. The following formula can briefly summarize the reaction principle:

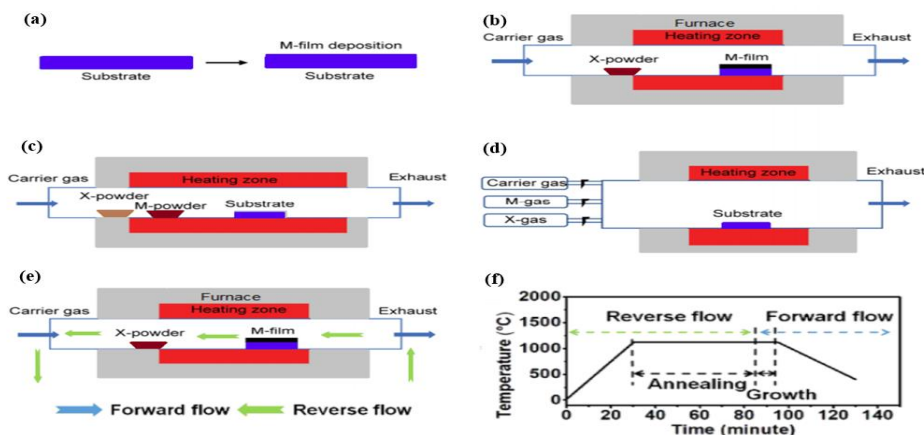


Figure 5. Schematics of CVD techniques for growth-2D-TMDs. Examples of common TVC procedures are shown in (a) and (b). (c) TVD procedures use a standard configuration. (d) A typical CVD setup using pure gas sources (e) A schematic representation of the DIY CVD system for the formation of ML/BL-WSe₂ nanosheets, in which the gas flow may be altered. (f) Temperature program of the enhanced two-stage thermal CVD method.

Choudhary et al. [37] Utilized magnetron sputtering to grow a Mo-thin film on SiO₂/Si substrate at 600°C. The prepared back-gate transistor has good characteristics, with 12.24 cm²/(V s) mobility and a switching ratio of about 10⁶. In the synthesis process of 2D-TMDs thin films, the substrate material is essential for the quality and uniformity of the thin films prepared. Laskar et al. [38] successfully prepared a big-size MoS₂ film by depositing 5 nm of Mo on a sapphire substrate and chalcogenizing it at 900°C. Buscema et al. [39] studied different substrates (SiO₂, h-BN, gold, etc.) for a single-layer influence of the Raman spectrum and photoluminescence spectrum (PL) of MoS₂. The results show that the difference in the substrate type will not introduce immense stress to the single-layer MoS₂, but it will cause a change in the doping level and enhanced PL. These results indicate the possibility of 2D-TMDs materials used in flexible transparent electronic devices. Bao et al. [40] found that MoS₂ transistor devices with polymethyl methacrylate (PMMA) as the substrate showed higher mobility; Chamlagain et al. [41] also observed that the MoSe₂ on the perylene-C substrate at room temperature. The mobility reaches 100~160 cm²/(V s), much higher than 50 cm²/(V s) on the SiO₂ substrate. They attribute this to the polar optical phonon scattering on the surface of the SiO₂ substrate. Alternatively, there is almost no such scattering effect on the perylene-C substrate. Su et al. [42] studied and compared the optoelectronic properties of SiO₂ and single-layer WS₂ on the sapphire substrate. The results showed that the degree

of coupling is not only between TMDs and substrate. Abderrahmane et al. [43] studied and compared the photogate effect, which was reduced in MoSe₂/SiN/Si, showing that SiN is a great substitute for silicon oxide as a gate dielectric material. It is related to the type of substrate. It is also related to the degree of bonding between the material and the substrate (even the same kind of substrate) and the excitation wavelength in the optical test.

As shown in Figure 6 (a)-(e), in the TVC method, the common techniques for depositing precursors using the target substrate include thermal evaporation [44], electron beam evaporation (EBV) [45] ALD [46], CVD [47], magnetron-sputtering [48], Pulsed-Laser Deposition (PLD [49], and dip-coating [50], etc. These source material film preparation methods can obtain large-scale, controllable thickness and good uniformity films on the target substrate. The precursor films prepared by thermal evaporation, electron beam evaporation, and dip coating methods have lower uniformity and film density than those obtained by magnetron sputtering, ALD, molecular laser epitaxy, and CVD, but the cost is low. In all these films, the grain size of the film layer obtained by the preparation technology is petite (usually <100 nm).

The TVC synthesis process combines the features of multiple source material film deposition methods to create transition metals (Mo, W, etc.). Tan et al. [51] used H₂S and MoCl₅ as the reaction Source. The MoS₂ thin film was prepared at 300°C and then heated

to 800°C to improve its crystallinity. Although their work has not yet proven the continuity of the thin film, it opens a new way for ALD to prepare 2D-atomic crystal thin films. At the same time, Jin et al.

[52] used dimethyl disulfide (CH₃SSCH₃) and Mo(CO)₆ as precursors to prepare MoS₂ at 900°C for thermal annealing to improve its crystallinity.

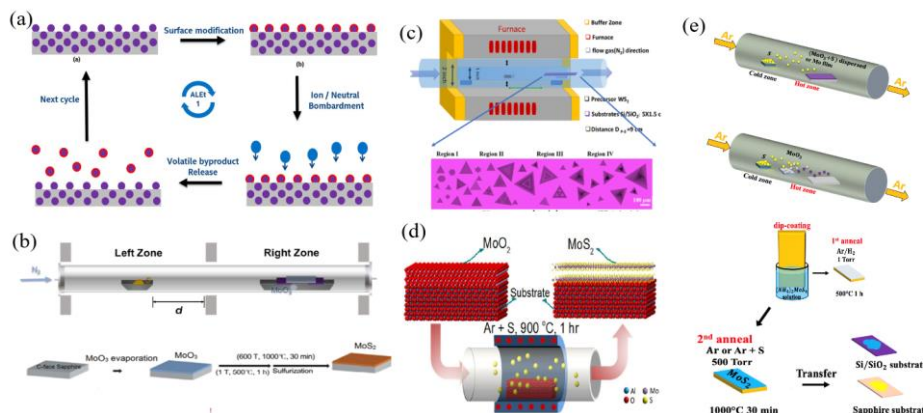


Figure 6. Method for preparing TVC using multiple ML-growth processes. (a) Schematic growth of WS₂ [53]. (b) Schematic of sulfurization process of sputtered MoO₃ to produce MoS₂ [35]. (c) Schematic Sulfurizing of thermally evaporated MoO₃ to growth MoS₂. (d) Schematic depicting the optimized sulfurization process [54]. (e) thermal vapor sulfurization process using a quartz tube, thermal vapor deposition process using a quartz tube, and thermal decomposition of (NH₄)₂MoS₄ [35].

The TVC synthesis process has the benefit of being able to manage halogenation, doping in the film deposition stage, and obtaining a wide area and high spatial homogeneity of TMDs atomic layer [55], but it is limited at this stage. The main reason for the application is that it is challenging to acquire high mobility and big grain size, limiting its development in actual production and specific applications.

2. 2. 2. Thermal vapor deposition

The preparation of 2D-TMDs films through TVD has been closely linked with the advancement of TVC technology. The process flow of various conventional TVD synthesis techniques is depicted in Figure 7(a)~ (c) and (f). The reaction quartz tube is utilized for the placement of sulfur powder, MoO₃ powder, and the target substrate (Fig 7(e), (f)) depicts the MoS₂ thin film that has been prepared. The present methodology for synthesis can be partitioned into four distinct stages: (1) The powdered source material is evaporated by heating or sublimation into the carrier gas. (2) The reaction material (usually an inert gas such as Ar or N₂) is transported through a specific rate of carrier gas, and the reduction reaction may also proceed at this stage. (3) The reactant is formed and diffused into the preset target substrate. (4) The adsorbed source material diffuses and migrates on the substrate, continues to pass through the reaction or re-evaporates, and then is discharged with the reaction byproducts with the carrier gas.

The researchers have invested much energy in the target substrate's surface treatment and topography design in recent years. The goal is to obtain growth conditions that are more conducive to the nucleation and deposition of 2D-TMDs, and, finally, obtain large size, high crystal quality, and thin films with good spatial uniformity. Currently, there are two main processing methods for substrates: 1ST is the cultivation of nucleation points on the substrate surface. For example, Lee et al. [56] found that spin-injection of nucleation promoters (such as graphene oxide (rGO), PTAS, etc.) to pretreat the target substrate is beneficial for Induced effective nucleation and layered growth during the growth of MoS₂. Najmaei et al. [57] also

successfully prepared the triangular MoS₂ sheets with a side length of 10 μm on untreated SiO₂/Si substrates. The findings suggest that nucleation promoters may not be a prerequisite for the growth of 2D-TMD films. 2nd is to use plasma gas (such as oxygen) to pretreat the surface of the target substrate. Zande et al. [58] did not introduce nucleation promoters. In the case of patterning of the substrate surface, the first use of acetone, isopropanol, and H₂SO₄/H₂O₂ (3:1) to carefully clean the substrate, then pretreat the substrate surface by using oxygen plasma to maximize the reduction. The exposure time of the small substrate, the precursor in the air, successfully grows a single layer of MoS₂ with a grain size of 120μm, and the synthesized film is shown in Figure 7(g) under an optical microscope.

Studies have shown that using MoO₃ as the Mo source can prepare an ML-MoS₂ with good crystallinity and triangles. Using MoCl₅ as the Mo source, thin films having a broad area, excellent homogeneity, and high controllability can be prepared [59]. In addition, crystalline MoO₂ can directly interact with the sulfur reaction and form a 2D-MoS₂ film. Wu et al. [60] used a catalyst-free vapor-solid growth mechanism of TMDs thin film synthesis method, high-purity MoS₂ powder was grown on the target substrate by simple PVD at 650°C. MoS₂ with a grain size of 20 μm was produced, which provides a new idea for synthesizing 2D-TMDs.

In addition to the substrate pretreatment and source material selection mentioned above, the concentration ratio of the two reactants in the gas phase transport process after high-temperature sublimation also influences the quality of the synthesized 2D-TMDs film. The concentration ratio, the distance between the two reactants, reaction, number of reactants, heating temperature of sulfur powder (or selenium powder), and carrier gas flow rate. Wang et al. [61] studied the precursor MoS₂ single crystal growth morphology under different concentration ratios of bulk Mo and S. Suppose that MoS₂ single crystal grows from a regular hexagonal nucleus, and then Mo and S atoms alternate to form three hexagonal sides. Under this theory, Mo and S grow separately. The difference in rate will lead to the final formation of different MoS₂ crystal shapes. Specifically, when the Mo:S growth rate ratio is more significant than 1:2, it grows to form an equilateral triangle; when it is equal to 1:2, it forms

a regular hexagon; when it is less than 1:2, it forms an inverted triangle. However, defects and other factors in the actual growth

process can also cause MoS₂ single crystals to exhibit irregular shapes other than triangles and regular hexagons.

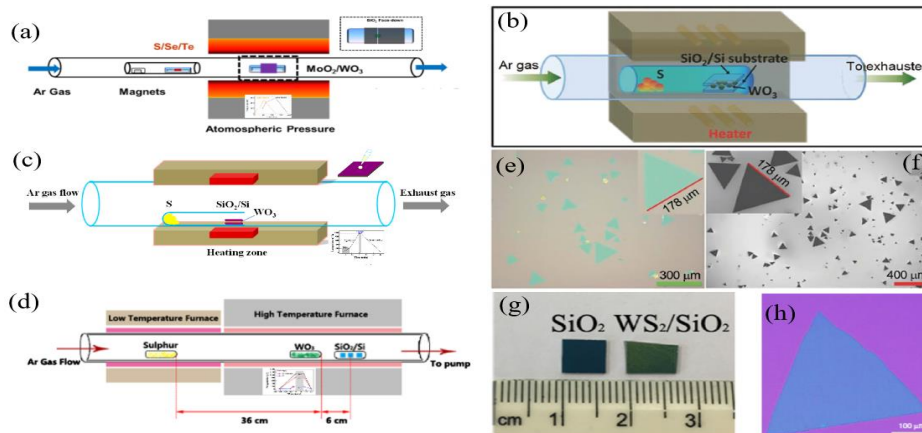


Figure 7. TVD method for growth 2D-TMDs. (a) Illustration schematic of modified NaCl-assisted CVD process. (b) Setup for the growth of WS₂ on SiO₂/Si [53]. (c) Schematic diagram of the horizontal single-zone furnace for synthesizing WS₂ on SiO₂/Si substrates [62]. (d) LPCVD setup system for synthesizing WS₂. (e, f) OM image and SEM image [63] respectively. (g) Photograph of SiO₂/Si before and after growth WS₂ [64]. (h) OM image, the transfer of a 400-mm ML-WS₂ onto a SiO₂/Si [62].

The formation of a 2D-TMDs film via the TVD method is subject to various conditions that impact its resulting morphology, including growth rate, crystallization state, growth temperature, reaction chamber geometry, pressure, carrier gas flow rate, source material dose, purity, as well as source material and the target substrate. The distance between them is related to many factors [65]. Unlike the TVC method, the TVD method is more inclined to obtain 2D-TMDs

single crystals with larger grain sizes and high quality. However, in terms of spatial uniformity, there are still many challenges to overcome on the scale and area scale. Because the optimization and regulation of growth conditions are also more complicated, it relies on experience accumulation to a large extent. It lacks repeatability, which cannot meet the needs of industrial production.

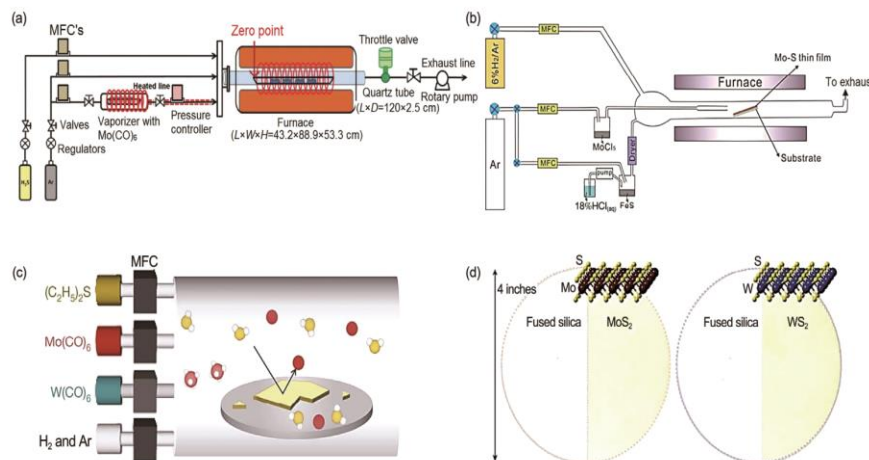


Figure 8. Schematic of CVD /MOCVD for synthetics of 2D-TMDs. (a), (b) Synthesis of different MoS₂ precursors using Typical gas-source CVD [47,66]. (c) MOCVD schematic for growing MoS₂ and WS₂. (d) OM images of ML-MoS₂, WS₂ grown on fused silica substrates [67].

2. 2. 3. Pure vapor source CVD and MOCVD

The straightforward process method of vapor-phase source CVD growth of TMDs is shown in Figure 8(a)–(c). Unlike the traditional CVD process, all reaction sources use vapor-phase sources, and each source can be individually controlled. This growth method has the advantage that the flow and temperature of each gas phase source

can be independently controlled simultaneously, combined with regulating growth temperature, and cavity pressure, and can better study the growth mechanism of 2D-TMDs films. This more refined growth regulation ability also can be used for heterojunction or multi-junction gold growth in energy band engineering research. Kranthi et al. used the CVD growth model of vapor source, as shown in Figure. 8(a), in which the Mo source uses Mo (CO)₆, the S source uses H₂S, studies the effects of growth parameters such as different

growth temperatures (350-850 °C), different deposition times (10 s-10 min), and different carrier gas flow rate. After growth, MoS₂ films were kept in an H₂S atmosphere for about 10 min. The grain size of MoS₂ films reached 20 μm, and the mobility of MoS₂ films was 2.4 cm²/(V s) at room temperature. Through a more complex MOCVD method, Kang et al. (Kang et al. 2015) used Mo (CO)₆ as the Mo

precursor, (C₂H₅)₂S as the S precursor and prepared a 4-inch wafer-level and high-density wafer on a SiO₂/Si substrate at 550°C. A high-quality single-layer MoS₂ film (Figure 8(c)) shows excellent spatial uniformity and good electrical conductivity performance (Figure 8(d)). The device has a mobility of 30 cm²/(V s) at room temperature and mobility of 114 cm²/(V s) at a low temperature of 90 K.

Table 2. Summary of various synthesis methods used for 2D-TMDs and their corresponding device qualities.

resolve resolution	material	Film size	Conductivity type	Current switching ratio	Mobility (cm ² / (V s), room temperature	literature
Micromechanical Exfoliation	MoS ₂	A few to tens of microns	N	~10 ⁸	(Single layer) ~200 (Multi-layer) ~ 500	[68] [69]
	MoSe ₂	A few to tens of microns	N	>10 ⁶	(Multi-layer) ~50	[70]
	WSe ₂	A few to tens of microns	N/P	>10 ⁶	(Single layer, N-type) ~202 (Single layer, P-type) ~250	[71] [72]
	WS ₂	A few to tens of microns	N	~10 ⁶	(Multi-layer) 60	[73]
	Liquid phase ultrasonic Exfoliation method	MoS ₂	Submicron, Reticulated structure film	N	>10	Multi-layer) ~0.01
Laser thermal ablation	MoS ₂	Tens of microns (controllable)	N	>10 ³	Single layer, 0.04~0.49	[32]
TVC	MoS ₂	Continuous film	N	~10 ⁴	~0.004~0.04	[38]
		Continuous film	N	~10 ⁵	~0.8	[74]
		Continuous film 5-20 μm	N	~10 ⁴ ~10 ⁶	~0.1~0.7	[61]
		Continuous film of About tens of nanometers	N	~10 ⁵	~6	[33]
		Continuous film 10-20 nm	-a)	~10 ³	~3.9	[75]
TVD	MoS ₂	Discontinuous film of About 160 nm	N	~10 ⁴	~0.02	[76]
		Discontinuous film About 50 μm	Bipolar	~10 ²	~0.28~0.46	[77]
Vapor source CVD	MoS ₂	Discontinuous film About 25 μm	N	~10 ⁵	2.4~7.1	[66]
		Continuous film 100 nm-10 μm	N	~10 ⁶	~10~40	[52]
	WS ₂	Continuous film 100 nm-10 μm	N	~10 ⁶	~5~18	[67]

In the various CVD growth methods, the big size of thin films 2D-TMDs, the substrate conditions, source material selection, and growth process parameters affect the quality of the prepared 2D-TMDs crystals. Compared with TVC or TVD Compared with the synthesis process, pure vapor source CVD growth has good development potential, and application value in controlling the growth reproducibility and spatial uniformity of 2D-TMDs. In

addition, the MOCVD method has more advantages in precise control and large-area growth. The significant advantage is a promising method for preparing 2D-TMDs films. However, the field continues encountering obstacles, including prolonged growth cycles, exorbitant expenses, and intricate equipment management.

2. 3. Summary of "top-down" and "bottom-up" growth models

The "top-down" growth model is currently only a supplement, a continuation of wafer-level large-area growth, and does not have the practical application conditions for large-scale production. In contrast, the "bottom-up" growth model is more suitable for industrial production and practical application requirements. The growth of most 2D-TMDs materials "bottom-up" still faces two significant challenges: (1) The growth area, grain size, film continuity, spatial uniformity, and thickness are still required. Further optimization of consistency, etc., while reducing costs and exploring relatively low-temperature growth; (2) In practical applications, specific substrate materials are usually required to support the obtained 2D-TMDs film, so corresponding transfer processes are required to peel them to the desired level. The complex transfer process is incompatible with the standard CMOS process on the substrate, which inevitably introduces problems such as film defects, cracks, and wrinkles. Before solving these problems of the "bottom-up" growth method, the actual process often requires some Make some compromises in performance. In response to recent research, the properties of field-effect transistor devices of TMDs prepared through the aforementioned methods are presented in Table 2.

3. Application of 2D-TMDs in electronic devices

In addition to achieving large-area growth of 2D materials, it also needs to be combined with micro-nano electronic device technology to realize their real applications in electronic and optoelectronic information devices. In recent years, as the size of silicon transistors continues to shrink, about to reach its physical limit, the emergence of 2D materials has attracted widespread attention in the academic community. For example, graphene has much higher mobility than bulk silicon and can suppress short-channel effects, which is important in the future integrated circuit industry. Important strategic significance, The zero bandgap properties of graphene restrict its potential use in electronic devices. [78]. In comparison, 2D-TMDs have a more extensive bandgap range. They can be selected material with the ideal forbidden bandwidth, ensuring that the mobility, switching ratio, sub-threshold swing, and threshold voltage are more balanced [79] simultaneously. The atomic-level channel thickness also strongly suppresses short channel Effect capability.

Research on TMDs electronic devices has developed from the performance demonstration of a single mechanically stripped 2D-Atomic crystal FET to photodetectors [80], sensors [68,70], more complex inverters, and various logic gates. Researchers from the Massachusetts Institute of Technology and the University of Vienna have recently used large-area grown 2D-TMDs to make preliminary attempts on complex logic circuits [71]. At the same time, new principal devices, such as tunnels based on 2D- materials, are also emerging. Through field-effect transistors and harmful capacitance effect logic devices [73], both have incredibly steep switching voltage conversion, which can meet the needs of low-power, high-speed logic devices.

In this context, the rise of 2D-TMDs semiconductor materials provides an excellent opportunity to develop new information devices. Explore the synthesis mechanism of "bottom-up" preparation methods expanding the applicability of such methods, and preparing them for Industrialized 2D-TMDs materials are the core of the development in the next few years; on this basis, a series of problems related to practical applications such as device structure,

process, and performance optimization are also urgently needed to be solved. In general, only through proper handling, by coordinating the relationship between "basic material characteristics-growth synthesis mechanism-device technology," can we be fully prepared for the future development and application of 2D- TMDs.

4. CONCLUSIONS

This study provides a comprehensive overview of the advancements made in synthesizing and applying 2D-TMDs. Various synthesis techniques, including chemical vapor deposition, mechanical Exfoliation, solution-based methods, and epitaxial growth, have been explored, highlighting their strengths and limitations. The distinctive properties of 2D-TMDs, such as the ability to tune the bandgap, robust light-matter interactions, and high carrier mobility, have created numerous opportunities for their application in electronics, optoelectronics, catalysis, energy storage, and sensing. Integrating 2D-TMDs into heterostructures and hybrid systems has yielded exciting progress, enabling the development of enhanced functionalities and novel device architectures. Nonetheless, challenges related to scalability, device integration, and stability in ambient conditions persist, necessitating further research and development endeavors. The future of 2D-TMDs holds great promise, and continued exploration in this field will pave the way for transformative technologies and contribute to advancements in various scientific and technological domains.

Competing interests

We declare no competing financial interest.

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From Lab to Field: A Systematic Review on Organotin Applications in Biological, Industrial, and Agricultural Sectors

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ABSTRACT

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The chemistry of organotin (IV) complexes has received a lot of attention in recent decades because of their wide applicability in numerous fields. The synthesis, identification, and use of organotin units as photo stabilizers, insecticides, medicines, and fire retardants are highlighted in this systematic study. These complexes' biological characteristics can be modified by altering the organic ligands, making them intriguing candidates for therapeutic uses. Furthermore, researchers are interested in the anti-oxidant capabilities of organotin (IV) compounds since they have high biological activity and function as free radical scavengers. Furthermore, these compounds have shown promise as photo stabilizers for several types of polymeric polymers. This study presents a comprehensive evaluation of the most important research studies utilizing organotin (IV) chemicals in both medical and industrial applications.

Keywords: organotin (IV) complexes; photo-stabilizers; biological activity; free radical scavengers.

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1. INTRODUCTION

Continuous developments in science and technology have resulted in substantial advancements in a variety of disciplines, addressing both new and existing difficulties confronting humanity. Among these developing topics, bio-organometallic chemistry has received a lot of interest, thanks to its amazing applicability in medical research. Bio-organometallic chemistry has arisen as a distinct area of research and development by integrating the disciplines of biochemistry and organometallic chemistry. Its main focus is on the incorporation of organometallic fragments into biomolecules, with metal-carbon bond chemistry playing a key role. The study of organometallic compounds in biological systems is the focus of bio-organometallic chemistry [1]. Several authoritative sources, including books, and review articles [2-6], have extensively covered tin (IV) complexes and their industrial as well as pharmacological applications. These resources highlight the extensive research conducted in the past few decades, underscoring the growing importance of this field. In recent decades, there has been considerable attention on the chemistry of organotin (IV) complexes, particularly about various biologically important compounds [7-9]. These complexes have found applications in organometallic synthesis, serving purposes in both industrial and medical fields. The biological properties of these complexes can be modulated by altering the organic ligands, thereby enhancing their reactivity. recently there are

many synthesized novel di- and tri-alkyl tin complexes utilizing cephalixin medication as a ligand, as depicted in Figure 1 [10]. These synthesized compounds have been employed as photo stabilizers for PVC (polyvinyl chloride) materials.

Several reputable sources have comprehensively covered tin (IV) complexes and their commercial and medicinal applications, including books and review papers [4-6]. These materials reflect the extensive research undertaken over the last few decades, emphasizing the field's expanding importance. The chemistry of organotin (IV) complexes has received a lot of interest in recent decades, especially about numerous physiologically relevant molecules [7-9]. These complexes have found use in organometallic synthesis, with applications in both industrial and medical domains. By changing the organic ligands, the biological characteristics of these complexes can be altered, increasing their reactivity. As shown in Figure 1, various novel di- and tri-alkyl tin complexes have recently been produced using cephalixin medicine as a ligand. These synthetic compounds were used as photo stabilizers in PVC (polyvinyl chloride) products.

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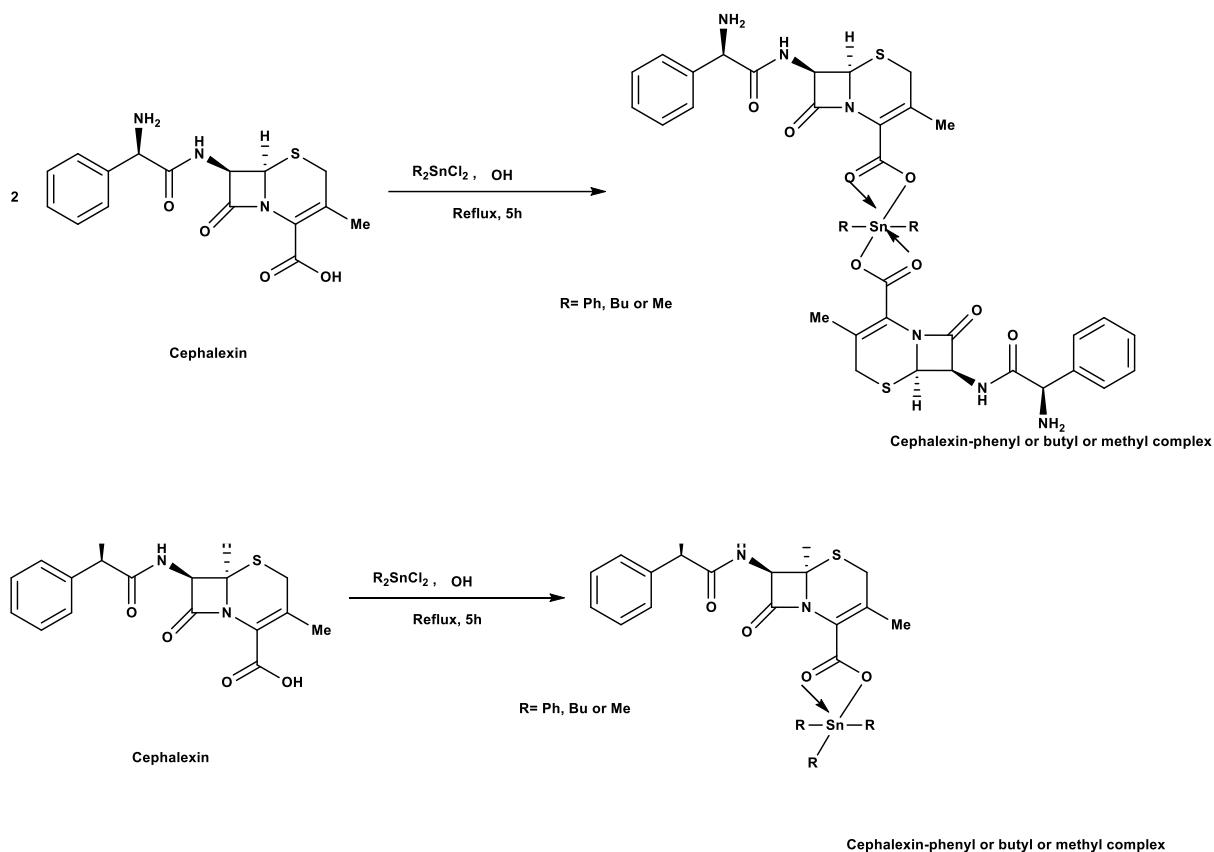


Figure 1. Syntheses of Di and triorganotin(IV) complexes with Cephalixin as a ligand [10].

Organotin compounds' wide range of uses in chemistry has substantially broadened their interactions with numerous biomolecules such as carbohydrates, amino acids, and peptides. Specifically, ligands classed as (O, O) donors can interact bidentate with organotin (IV) molecules, producing chelate rings with five or six members. Notably, classic ligands with two oxygen atoms, such as hydroxamic acids, continue to fascinate significant attention due to their profound biological effects and potential as tumor growth inhibitors [11-13]. Hydroxamic acids have long been recognized as effective organotin ligands. Several research on the biological activity of organotin compounds, including anticancer qualities, have demonstrated that organotin (IV) compounds (R_2SnX_2) and their complexes containing Sn-O, Sn-N, or Sn-S bonds frequently exhibit substantial biological effects. The specific method by which organotin (IV) complexes exert their biological activity is unknown and varies amongst chemical compounds [14-16]. However, it has been proposed that the presence and arrangement of leaving groups surrounding the Sn (IV) ion, which influences the form and strength of the complexes' Sn-S and/or Sn-N bonds, plays an important role in determining the biological activity of these molecules.

Furthermore, many organotin hydroxamic acids have a wide range of biological features, including fungicidal, insecticidal, and anticancer activity, making them stand out. Because hydroxamic acid contains nitrogen (N) and oxygen (O) atoms, it is favorable to the formation of physiologically active organotin complexes. Previous research has shown that organotin (IV) bis hydroxamates have a wide range of biological action against various tumor types [17-19].

Extensive study is now being conducted into the synthesis, stability, structure, and reactivity of organometallic cation-containing molecules with physiological action. Notably, research into the role of organometallic cations in metabolism has yielded ground-breaking results that demonstrate the importance of naturally occurring chemicals and processes. Because of their permeability, biomolecule ligands, noted for their amazing diversity, can interact with molecules of precise stereochemistry. Biomolecular ligands can be produced, changed, stabilized, or triggered by including organometallic fragments, allowing for their deliberate application in biomedicine. Organometallic compounds have earned worldwide attention for their therapeutic and restorative potential, contributing to breakthroughs in medical procedures and, ultimately, improving human life [20-22].

Scientists from diverse disciplines are working together to learn more about the roles of organometallic compounds in living systems. They are investigating advanced organometallic approaches to examine biological processes and obtain a deeper knowledge of the metabolic processes at work. The investigation of the roles of organotin (IV) compounds in biological systems is one notable area of research. According to studies, these chemicals are highly active as biocidal, antimicrobial, antibacterial, and anticancer agents. This discovery has motivated bio-organometallic chemists to focus on creating metal chelates with biological activity that can be given successfully within biological systems. There is abundant evidence in the literature to suggest the anticancer action of organotin (IV) compounds [23,24]. Complexes containing electron-donating elements such as oxygen, nitrogen, and sulfur

are thought to be capable of forming physiologically active complexes, particularly when the bonds are formed by intramolecular coordination.

2. Organotin Compounds Applications

Organotin compounds demonstrate a wide range of biological actions, capturing the attention of scientists in recent years. Several complexes have been discovered to be effective antifouling, antibacterial, and antiviral agents. As a result, their potential in cancer prevention has sparked substantial interest. Notably, bactericides and fungicides containing triphenyl tin and tributyltin are commercially available, confirming their potency. Figure 2 depicts photographs of antibacterial organotin compounds, demonstrating their potent biological activity against several bacterial strains. ACTINOMYCETES, which are GRAM-POSITIVE creatures, are very numerous in soil and can be found in a variety of settings. They have emerged as major producers, accounting for two-thirds of all known antibiotics produced by bacteria. The investigation into siderophore analogs has generated significant interest in their potential application as medicinal medicines, specifically in chelation treatment [25].

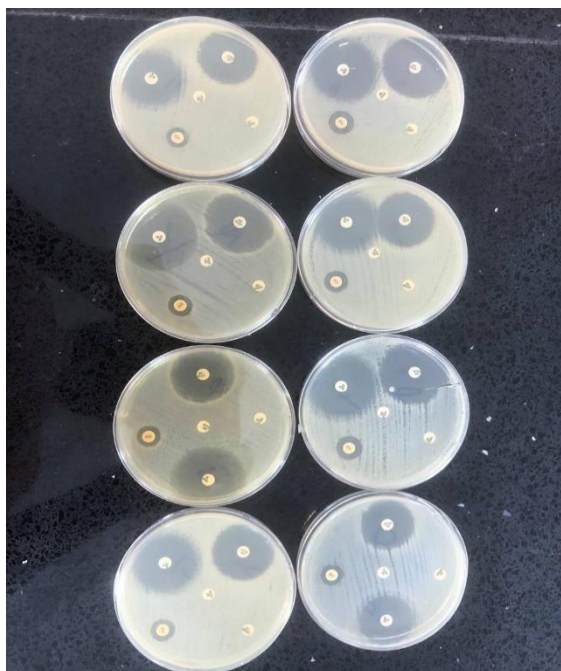


Figure 2. Antibacterial organotin compounds Images

Several investigations have been conducted to investigate the possibility of manufacturing anticancer organotin (IV) derivatives from physiologically relevant substrates. Several organotin complexes with promising in vitro anticancer properties have been found in these studies. Researchers have successfully produced and tested a wide range of organotin (IV) complexes for their potential as anti-tumor drugs. As a result, these complexes show potential as viable options for developing anticancer organotin chemicals [26].

3. Medicinal chemistry

Medicinal chemistry research has looked into the potential of organotin complexes as anticancer and antimicrobial medicines. These complexes have shown intriguing properties,

including selective toxicity to cancer cells and the possibility of producing anti-cancer medicines. Furthermore, studies on the antifungal, antibacterial, and antiviral activity of organotin complexes have been conducted, paving the way for the creation of novel antimicrobial drugs [27-29]. Organotin compounds, a type of chemical compound composed of tin atoms bound to organic groups, have received a lot of attention because of their prospective applications as anti-cancer and anti-microbial agents. Preclinical research has provided promising results, demonstrating the specific toxicity of particular organotin complexes against cancer cells while protecting the viability of healthy cells. Although the specific mechanism of action of these complexes is unknown, it is assumed that they impair essential cellular processes required for cancer cell survival [30,31].

Animal husbandry has made use of organotin compounds, such as insecticides for sheep and cattle and anti-helminthics for chickens. In commercial formulations, dibutyltin dilaurate is mixed with piperazine and phenothiazine to treat worm infestations in hens [17].

4. Industrial

Antifouling paints containing tin compounds were extensively used to prevent aquatic creatures such as bacteria, algae, and marine animals such as hydroids, crabs, mollusks, and tunicates from adhering to surfaces. Triorganotin compounds were introduced as an active ingredient in these paints in the early 1960s. However, repeated exposure to these compounds resulted in the emergence of tributyltin fluoride as a dangerous compound over time. A subsequent experiment demonstrated that tributyltin compounds harmed the growth of Pacific oysters [32]. While many nations have laws limiting the use of tributyltin compounds on vessels less than 25 meters in length, they are nonetheless used on occasion.

Organotin complexes have long been employed as photo stabilizers in a wide range of applications. Because of their capacity to absorb and spread UV light, these complexes have excellent photostabilizing capabilities. Tri and organotin chemicals are among the most often utilized organotin complexes. The use of organotin complexes as PVC (polyvinyl chloride) photo stabilizers has decreased dramatically due to environmental concerns. Organotin compounds, particularly those having tin (IV) as the main atom, could prevent UV-induced PVC breakdown [33].

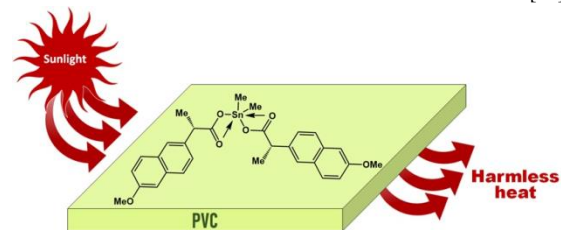


Figure 3. Effect of UV Irradiation on Naproxen Diorganotin(IV) Complexes on Poly(vinyl chloride) Films [33]

These complexes diffuse and absorb UV light, acting as photo stabilizers by preventing chemical reactions that would otherwise degrade PVC. They accomplish this with PVC to create stable complexes that aid in the long-term preservation of the material's mechanical qualities and aesthetic appeal [34-36].

4. Agriculture

Organotin complexes play a crucial role in modern agriculture as they serve as effective fungicides and bactericides,

safeguarding crops against fungal and bacterial diseases. These complexes have demonstrated remarkable efficacy in managing plant diseases caused by fungi and bacteria, making them invaluable tools in agriculture [37-39]. Among the notable organotin complexes employed as fungicides in agriculture, tributyltin oxide (TBTO) stands out. With the chemical formula $(C_4H_9)_3SnO$, TBTO acts as a potent fungicide by disrupting the cell membranes of fungi and bacteria, thus impeding their growth. The mode of action of TBTO involves its binding to the sulfhydryl groups (-SH) present in enzymes responsible for ergosterol synthesis—a critical component of fungal cell membranes. This binding process inhibits the synthesis of ergosterol, ultimately compromising the integrity of the fungal cell membrane. Consequently, the fungal cell experiences leakage of its contents, leading to the demise of the fungus [40,41]. The effectiveness of TBTO as a fungicide has been extensively demonstrated in various crops, including rice, wheat, soybeans, and numerous others. Furthermore, TBTO has found utility as a bactericide in animal husbandry, effectively combating bacterial infections in livestock.

5. Toxicity of Organotin Compounds

Tin in its inorganic form is considered non-toxic. Because of their poor absorption, low solubility, fast elimination, and low accumulation in tissue, inorganic tin compounds pose little toxicological concern; nonetheless, the toxicological pattern of organotins is exceedingly complex.

The number, type, and nature of chemical groups R (where R= alkyl or aryl group) attached to the Sn cation determine the biological effects of the compounds. The secondary role is played by inorganic anion X. The toxicity of organotins to microorganisms reduces in the following order: $R_3Sn X > R_2SnX_2 > RSnX_3$, with R_4Sn compounds being the least toxic. Triphenyltin, tributyltin- and tripropyltin are the most hazardous in general, with cell membrane interaction being a crucial precondition for toxicity [42,43].

6. CONCLUSIONS

The discovery of numerous new organotin complexes and their diverse applications has sparked significant interest among scientists in the design and synthesis of these compounds for various purposes in biology, industry, and agriculture. Organotin (IV) compounds have demonstrated remarkable biological activity, particularly as anti-mycobacterial, antifungal, and antioxidant agents. Moreover, they have proven valuable in agricultural settings as additives for crop protection. One notable advantage of organotin (IV) compounds is their reduced harm to non-targeted organisms, owing to their low photo-toxicity and ability to readily degrade in the environment, ultimately producing harmless tin residues. Lastly, organotin (IV) compounds have exhibited excellent performance in industrial applications such as wood preservation, antifouling coatings, and plastic photo-stabilization.

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Overview of the Rising Temperatures and the Global Warming Crisis in the World and Iraq

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The gradual increase in earth's temperature brought on by the buildup of greenhouse gases in the atmosphere is referred to as "global warming." The planet's temperature rises as a result of these gases' capacity to absorb infrared radiation.

Human activities that contribute to the rise in Earth's temperature include the usage of fossil fuels (coal, petroleum, and gases), deforestation, and increased animal husbandry, all of which emit considerable quantities of greenhouse gases into the atmosphere.

Natural causes such as climate change and natural variations all affect the Earth's temperature, precipitation, and volcanic activity.

The increase in water volume and melting of the polar ice caps are two unfavorable outcomes of global warming, which also causes sea levels to rise. This might lead to flooding and the extinction of marine life habitats. Changing precipitation patterns and bringing on droughts, floods, thunderstorms, and hurricanes, also has an impact on agriculture, human health, and the environment . Global warming also has an effect on ecological systems, which changes the biodiversity and health of the ecosystems. The topic of global warming is discussed in the paper, along with its causes, dangers, and potential solutions. Finding and exploiting renewable energy sources is one of the most effective ways to stop the planet from warming up more.

Keywords: Global warming; Environment; Human activities; Solar radiation.

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1. INTRODUCTION

Because of the accumulation of greenhouse gases in the atmosphere, the average surface temperature of the Earth has been steadily rising. The phenomenon is known as "global warming." These gases prevent solar heat from escaping into space, which would otherwise warm the entire planet. Carbon dioxide, which is produced by human activities including the burning of fossil fuels, deforestation, and industrial operations, is the most important of these greenhouse gases [1-3].



Figure 1. Global Mean Temperature 1951-2020 [4].

The graph shows the fluctuation in global surface temperatures between 1951 and 1980 in proportion to their mean values. According to data from NASA's Goddard Institute for Space Studies, the two warmest years on record are 2016 and 2020 [4].

2. Causes of Global Warming

The surface of the Earth has more pleasant and consistent temperatures than the other planets in the Earth's solar system, which are either blazing hot or cruelly cold. This fortunate position is due to the Earth's atmosphere, a thin layer of gases that encircles and protects the globe. Nonetheless, the great majority of climatologists and academicians (97%) believe that human activity has significantly altered the Earth's atmosphere over the last 200 years, producing global warming.

Global warming is primarily the fault of humans. When fossil fuels like coal, gas, and oil are used, large volumes of carbon dioxide are released into the atmosphere. The Earth's temperature rises because of these gases' ability to retain solar heat. The transportation industry is the largest contributor to carbon dioxide emissions, followed by the energy sector and the industrial sector [5-7]. A big additional factor causing global

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warming is deforestation. Trees breathe forth oxygen and absorb carbon dioxide from the atmosphere through a process called photosynthesis. Due to logging, burning, and other forms of forest loss, there are fewer trees available to absorb carbon dioxide, increasing the amount of greenhouse gases in the atmosphere.

To completely grasp the concept of global warming, one must first understand the greenhouse effect. Figure 2 shows how the natural greenhouse effect causes the atmosphere to frequently retain some heat, preventing our planet from freezing. On the other hand, human-induced greenhouse effect enhancement leads to global warming. The biggest contribution to this phenomenon is the burning of fossil fuels, which raises the concentration of greenhouse gases such as carbon dioxide, methane, and nitrogen oxides in the atmosphere [2].

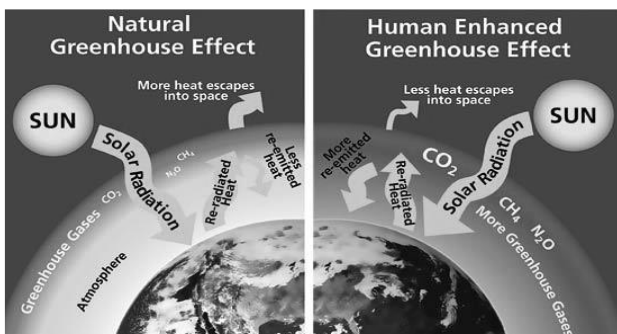


Figure 2. Types of Greenhouse Effects [8].

The greenhouse effect, so named because of how a greenhouse works, is the term used to describe the interchange of incoming and outgoing radiation that heats the Earth, Fig. 3. Entering UV light from the outside may easily travel through a greenhouse's glass walls and be absorbed via plant life and other solid substances within. The greenhouse heats up as a result of the weaker infrared radiation being unable to flow through the glass walls and becoming trapped. Due to this phenomenon, tropical plants can flourish indoors throughout the winter [8].

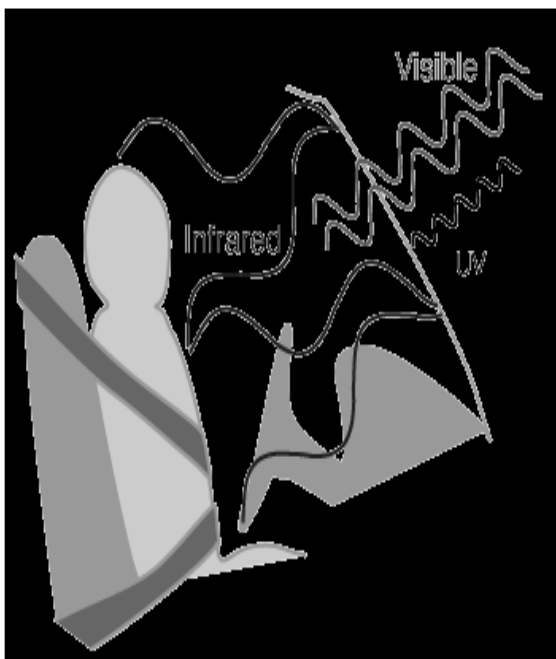


Figure 3. Greenhouse effect [9].

The same thing happens when a car is parked outside on a chilly bright day. The interior of the car is heated by the sun, but any thermal radiation that tries to egress is contained by the windows that are closed. The temperature inside the car is effectively raised by the trapping. The heated air that is contained does not convect, so it does not lose energy. Fig. 4 illustrates this occurrence.

Methane, generally known as natural gas, is the second-most significant greenhouse gas. It is produced as a result of numerous agricultural activities, including cow digestion, paddy rice cultivation, and manure application. By using ineffective waste management techniques, methane is produced. On the other hand, the usage of fertilizers is the primary contributor to the production of nitrous oxide. Chlorofluorocarbons (CFCs), a type of fluorinated gas, are principally produced by refrigeration and several industrial activities [10,11].

Global warming is a result of a variety of natural phenomena, such as volcanic eruptions, solar radiation, modifications to the Earth's orbit, and vertical tilt. Although significant, these factors are insignificant when compared to the impact of human activities.

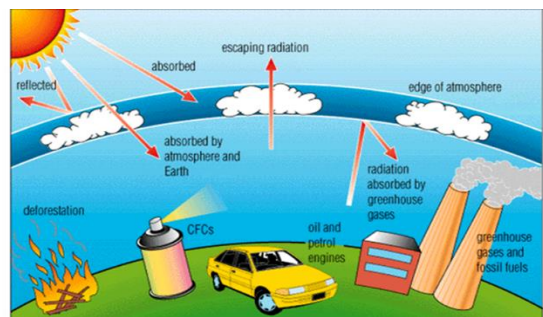


Figure 4. Illustration of Global Warming [12].

3. Resulting from global warming

The environment and human society are both negatively impacted by global warming in various ways. These outcomes comprise:

1. **Rising Sea Levels:** As the Earth's temperature rises, glaciers and polar ice caps melt, raising the sea level as a result. As a result, low-lying region people are evicted, there is flooding, and marine species lose their homes [13–15].
2. **Extreme Weather phenomena:** As a result of global warming, heatwaves, droughts, floods, storms, and other extreme weather phenomena occur more frequently and severely. These incidents may cause a substantial impact on infrastructure, agriculture, and human health [16,17].
3. **Loss of biodiversity:** The distribution and survival of plant and animal species are impacted by the consequences of global warming. This might wipe out entire ecologies and the people that depend on them [18–20].
4. **Health Impacts:** Due to the growth in heat-related illnesses, respiratory issues, and the advent of vector-borne diseases like malaria and dengue fever, global warming may have a considerable negative impact on human health [21–23].

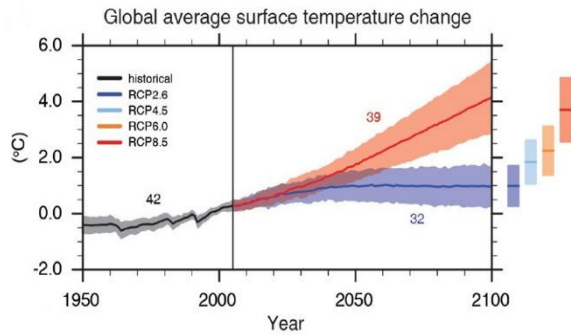


Figure 5. Global Average Surface Temperature Change [24].

According to the research, surface temperatures will keep increasing. Temperature increases due to future greenhouse gas emissions might range from 0.3 °C to 4.8 °C [25].

4. Global warming in Iraq

Global warming is not centered on Iraq; rather, it is a global phenomenon that affects every country in the world. Climate change is a result of greenhouse gas concentrations growing over time. Events including global warming, droughts, and the loss of agricultural land have an impact on every corner of the earth.

The three most abundant gases in the atmosphere are carbon dioxide, methane, and nitrous oxide. As a result of these gases' capacity to absorb solar energy that would otherwise bounce back into space, the temperature of the Earth's surface and atmosphere may increase [26].

Every region of the world is impacted by global warming; however, some may be more severely affected than others. This may be influenced by a variety of variables, including regional climatic trends, land use practices, and sensitivity to extreme weather events.

In the case of Iraq, the country is located in a region that is prone to sweltering heat and dry weather. A number of the most severe effects of climate change, such as more frequent and severe heat waves, droughts, and dust storms, are anticipated to be felt most severely in the Middle East and North Africa region. These changes will have a considerable impact on the region's economic development, food security, and public health [26–28].

Additionally, there has been a recent rise in war and political instability in Iraq, which has exacerbated the effects of climate change. Conflict can have an impact on social services, food systems, and infrastructure, making populations more vulnerable to the consequences of bad weather.

Despite these challenges, steps can be taken to decrease global warming's effects in Iraq and worldwide. This includes preserving and regenerating the natural ecosystems that can absorb carbon from the atmosphere, reducing greenhouse gas emissions through the use of clean energy sources and energy-saving practices, and boosting adaptability to the effects of climate change through preparedness for natural disasters.

It is crucial to recognize that global warming is a problem that affects the entire world and requires a concerted effort from all countries. It is our joint responsibility to take action to safeguard the environment and guarantee a healthy future for future generations, even though certain places may be more severely impacted than others [29–31].

5. Global Warming Solutions:

Reduced greenhouse gas emissions are critical to fighting global warming. This is achieved by:

1. Transition to sustainable Energy: By investing in sustainable energy sources like solar, wind, and hydropower, businesses and governments may lessen their dependency on fossil fuels.
2. The Efficiency of Energy: Improving the efficiency of energy use in buildings, transportation, and industry may reduce the amount of energy utilized as well as greenhouse gas emissions.
3. The quantity of carbon dioxide that is absorbed from the atmosphere and stored in the soil may rise as a result of reforestation. Planting trees and restoring forests help to achieve this.
4. Sustainable Agriculture: Using sustainable agriculture methods can lessen land-use changes and livestock-related greenhouse gas emissions.

6. Iraq's solution to global warming

The effect of global warming is an issue that must be addressed, and Iraq, like all other countries, must contribute to the solution. While Iraq may not be one of the largest greenhouse gas emitters, it is still affected by the consequences of.

One solution to global warming that could be concentrated in Iraq is investing in renewable energy. Iraq has vast potential for solar energy due to its location in the Middle East, where it receives abundant sunlight throughout the year. Investing in solar energy infrastructure, such as solar farms and rooftop solar panels, could help reduce Iraq's reliance on fossil fuels and decrease its carbon footprint. The dangers that come with global warming are enormous. The usage of fossil fuels like coal, Natural gas, and oil exacerbates This issue further. It is crucial to immediately stop utilizing fossil fuels. The first and most effective approach to prevent this catastrophe is to adopt alternate energy sources. These include geothermal, biomass, solar, wind, and hydropower. Utilizing these sources is fantastic because of how ecologically friendly they are. They don't create any harmful gases or chemicals that can hasten global warming. They are ecologically friendly and pose no damage to the balance of ecosystems [31].

Most importantly, we will ultimately need to move to renewable energy sources to fulfill our energy demands once fossil fuels are depleted. Therefore, using alternative energy sources is the greatest way to stop global warming. Using renewable energy sources might shield the world from the hazards of global warming, as seen in Fig. 6.

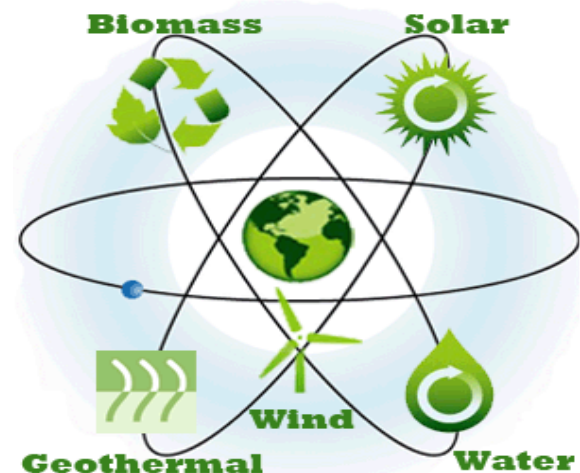


Figure 6. Renewable Energy Sources [32].

The promotion of energy efficiency is another issue that Iraq may concentrate on. Encouragement of the use of energy-efficient appliances, building regulations that demand energy-efficient construction, and public awareness programs that encourage energy-saving practices could all help achieve this. These initiatives might result in a decrease in energy use, which would eventually result in a decrease in greenhouse gas emissions [33–35].

Additionally, Iraq has a substantial agricultural industry that might be utilized to lessen the consequences of global warming. Iraq's fertile soil might be used for reforestation and afforestation initiatives because planting trees and other vegetation can help trap carbon from the atmosphere. The agricultural industry in Iraq might also be updated and made more effective, lowering greenhouse gas emissions from agricultural techniques and ensuring the population's access to food [36].

The promotion of recycling and trash reduction are two other possible solutions that might be focused in Iraq. Iraq produces a lot of waste, and many of its landfills are not properly maintained, which causes methane emissions. The amount of garbage produced and the emissions related to waste management could both be decreased by promoting recycling and waste reduction [37,38].

According to Figs. 7 and 8 only 48% and 52% of the researchers correctly defined and identified the main driver of climate change, respectively. The researchers' response data is shown in Table 1 [36].

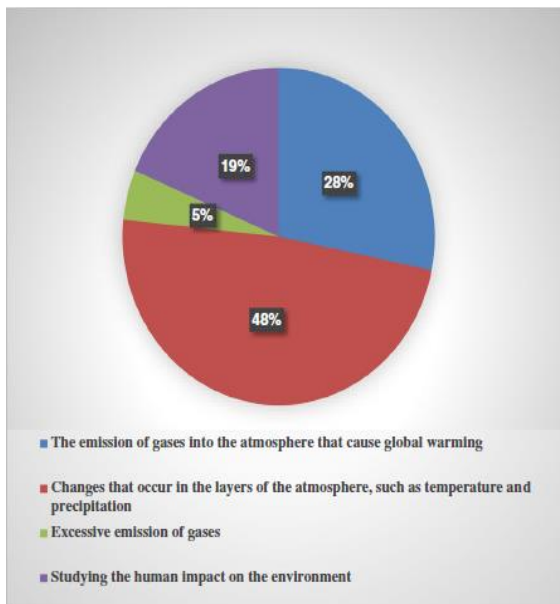


Figure 7. Description of climate change as understood by respondents [39].

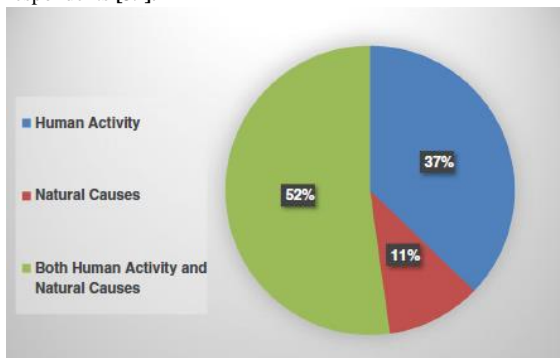


Figure 8. Respondents' understanding of climate change [39].

Table 1. Data on respondents' perceptions of the causes of climate change.

Questionaries	Response	Responses	
		Percent	Frequency
What definition of climate change is the most precise?	the atmospheric gas emissions responsible for global warming	28.2	297
	Temperature and precipitation changes that occur in the layers of the atmosphere.	48.4	509
	Excessive emission of gases	4.8	50
What, in your opinion, is the primary cause of climate change?	investigating how people affect the environment.	18.6	196
	1-Human activity, including the burning of fossil fuels, population growth, increased industrial activity, and an increase in the number of automobiles and petrol emissions.	37.2	391
	2- Natural events (increased solar activity and eruptions of volcanoes)	10.6	112
	3-Both human activity and natural causes	52.2	549

Finally, Iraq could focus on international cooperation to address global warming. As a member of the international community, Iraq might collaborate with other nations to advance international frameworks and agreements that aim to lower greenhouse gas emissions and lessen the consequences of global warming. This may entail cooperating with other nations to put the Paris Agreement into effect, which aims to keep warming to under 2°C. over pre-industrial levels.

In conclusion, while Iraq may not be one of the largest contributors to global warming, it is still affected by its consequences. Iraq could concentrate on solutions such as investing in renewable energy, promoting energy efficiency, utilizing its agricultural sector, reducing waste, and promoting international cooperation. These efforts could help Iraq reduce its carbon footprint and mitigate the effects of global warming while contributing to global efforts to address this critical issue.

7. Other Solutions

Limiting the use of automobiles that emit harmful emissions might aid in the reduction of harmful emissions, which are a major contributor to global warming. This has not been particularly successful since many individuals are hesitant to limit their usage of carpooling. Undoubtedly, some people have begun to use bicycles and public transport, while others choose to walk, but these numbers remain fairly small. It should be noted that while selecting a car, fuel efficiency and pollution are key factors to consider. People should commute with friends or coworkers to reduce the total number of autos on the road.

Print and social media can be utilized efficiently to aid in the resolution of the problem.

Another excellent approach for slowing global warming is recycling. People should utilize rechargeable batteries instead of throwaway ones.

Even little individual acts, such as switching from incandescent to compact fluorescent lighting, can have a significant impact on the fight against global warming. Start planting a lot of trees right away. Stop deforestation and make use of renewable energy. Also seriously pursuing renewable energy sources (such as biomass, solar, wind, hydro, and geothermal). Finding and exploiting renewable energy sources is one of the most effective ways to stop the planet from warming up more.

Being able to predict future waste pathways for solar energy systems requires knowledge of solar panel failures. To reduce the premature failure of solar panels, manufacturers must identify ways to improve their reliability and service life. However, it was not clear if the panels were defective or if there was another explanation for their removal.



Figure 9. Depicts a symbolic illustration of how to stop global warming [40].

8. CONCLUSIONS

An important environmental and societal problem is global warming. Human actions like the combustion of fossil fuels and deforestation are its main causes. In addition to increasing sea levels and harsh weather, global warming also has a deleterious influence on human health. To combat global warming, greenhouse gas emissions must be decreased through the use of renewable energy, energy efficiency, reforestation, and sustainable agriculture. To safeguard the environment and guarantee a sustainable future for all people, action must be taken right now to reduce global warming.

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Impact of computer simulation on the evolution of applied and educational research

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ABSTRACT

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Recently, there have been many means and techniques for teaching physics, and they have been classified into different types of auxiliary methods that simulate the real laboratory and work to bring the researcher's imagination closer to visualizing some difficult physical theories. It is noted that the researcher's interest and appreciation for the universality of science and the way to treat it in practice is almost non-existent. Because science represents the simplest and most difficult experiences of everyday life, it can be argued that learning science should be a natural or automatic consequence of something related in a prescribed manner. However, in many cases, neither the curriculum nor the textbooks reflect the science Common denominators and the importance of science. And so constantly we will find that experienced researcher is Not prepared to delve into abstract concepts and connections related to science topics and the instructions on which it is based, and laboratory tests are often presented and are dependent on previous information and the sciences that are considered the basis for it and that he needs.

A concrete inquiry-based process is not only important for fostering interest but also for proving the importance of a scientific topic and solving a specific problem.

The purpose of this study is to draw attention to the importance of these conceptual changes, which effectively contributed to Understanding Physics Experiments.

In this paper, we used a simulated laboratory application (PHET) and a practical laboratory application (HLE) in the Faculty of Science and the Faculty of Education, University of Tobruk, Libya.

Keywords: C++, CUDA, Krubach's alpha method, Bloch equations, Fourier transforms

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1. INTRODUCTION

Engineering majors are a vital part of the economy of countries, and the most important of them are professions filled with unqualified graduates. To solve this employment gap, it was necessary to improve and enhance STEM education, particularly in the preparatory years of university education [1]. Various methods have been used in practical colleges, such as Revising curricula, evaluating science, technology, engineering, and mathematics, increasing the use of technology, and demanding funding for research and studies. In-depth study of basic engineering science, conducting a practical graduation project, etc. To meet this need, educational courses and educational programs have been approved Computer simulation These courses include concepts of learning by performing labs and designing and creating models with the increasing use of simulation effectively, these procedures have become essential in applied sciences, as they are considered an addition to Laboratory experiences assisting the researcher [2].

This was the prevailing view of the scholars It is the use of simulation in the close observation of experimental phenomena

to identify and collect data to support new theories and the researcher should engage in similar activities to prepare himself to be able to raise his efficiency and perform his scientific tasks better .

Nowadays, careful focus has been placed on laboratory experiments because of their importance It offers important benefits that directly affect the material output of research and scientific studies [3-5].

The use of practical tools and devices, and programmed simulation techniques during data collection, contribute to building models that are similar to reality, and such treatments work to confirm the validity of the theories and hypotheses on which they are based. Simulation laboratories have contributed to helping students and researchers for a deeper understanding that can help the effective use of the practical laboratory and thus acquire additional skills and necessary experience, exchange information and ideas, and transfer theoretical knowledge .

into practical applications [6]. The hands-on lab helps develop innovation and critical thinking skills. It may be a

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motive to know the materials and equipment used in the laboratories and work to find the ideal methods in preparing and preparing for realistic experiments, and this is what enhances the researcher's confidence and confirms the work steps .Many studies have shown that practical activities help the researcher to excel in performance And follow the traditional scripts [7] Also, they enhance information and replace knowledge in scientific concepts [8]. Which is considered to develop positive attitudes towards science [9] and encourage talent .

Creativity in solving specific scientific problems, enhancing the independence of researchers and improving their skills in scientific research that requires good induction, accurate calculations, and serious communication [10].

2. Methodology

Researchers need to conduct experiments because they allow them to apply theoretical concepts by dealing with devices, equipment, and data, and to build and enhance knowledge and skills, which will have a vital and influential role in the future [11]. This knowledge and competencies can be developed not only in traditional laboratories (hands-on) but also using computer simulations and remote laboratories. These online resources in addition to allowing the researcher to practice some experimental skills activities differently, are an incentive for the younger generations of digital researchers [10]. Of course, these researchers should be aware that they are getting different experimental results from these resources: real results from remote labs rather than computational model results from simulations. A “hybrid” or “hybrid” approach to laboratory learning—a combination of hands-on labs, simulations, and remote laboratories—appears to be the most effective [12]. In addition to the use of cross-cutting techniques and resources, it may allow the supervising expert to reach more researchers [13]. Remote labs combine the advantages of both hands-on labs and simulations and are defined as an educational resource where the user and tools are physically separate. Communication between them is done using the Internet and user interaction with the tester (configuration, control, and/or monitoring of results) is achieved through a computer or smartphone interface [14]. PhET (Virtual Machine Systems in Reality) is the most widely used electrical and electronic circuits laboratory. And since 2015, it has been the best remote-controlled laboratory .It contains the capabilities of controlling the parameters and values, with the same tools and components available in the real lab (22) By addressing this topic, we hope to create similar simulation systems at the University of Tobruk, which will raise the level of study and the efficiency of higher education outputs (HEI) and also contribute to the convergence of the level of postgraduate studies in five different countries (23).

Our main goal is to provide the researcher at the University of Tobruk with contextual approaches (through electrical circuit analysis). We as experts already have this desire/interest in technology that creates interesting mechanisms for transmitting information to the researcher being a more productive approach to learning and exploring science and concepts [15]. On the other hand, the physics course contains a unit for analyzing electricity and electrical circuits, so we decided to use this simulation program to prove the relationship between the software technology and compare the results from it with the remote laboratory, which works to develop experimental skills and competencies as supported by many authors [16-18] While collecting data from the program implementation results, an important gap was identified between the researcher's understanding of simulations and remote laboratories. To describe and analyze the specific

problem, we described the environment of the experiment that was conducted, including the equipment, instrumentation parameters used, and other resources with a great focus on the activity involving PHET .

3. Practical

applications to find the difference between simulation and remote laboratories:

In this realistic experiment, we connect the circuit as shown in the figure to obtain the resistance (R) of a specific wire (resistance coil) according to Ohm's law

$$\frac{V}{I} = R$$

Where, V: the potential difference between the ends of the selected resistance coil. (conductor)

I: the intensity of the current flowing through it .

If L is the length of the resistance wire, then the resistance per 1cm of wire

$$=R/L$$

voltmeter range

$$3 =v$$

Ammeter range

$$500 =mA$$

Lowest voltmeter reading

$$0.05 =v$$

The lowest reading of the ammeter

$$10 =mA$$

Zero error in ammeter reading

$$e1 = 0$$

Zero error in the voltmeter reading

$$e2 = 0$$

Sr. No	Ammeter Reading I(A)		Voltmeter Reading V(v)		V/I= R
	Observed	Value	Observed	Value	
1	50	500 mA	16	16*0.05 =0.8	1.6Ω
2	35	350m A	11	0.55	1.57 Ω
3	32	320m A	10	0.50	1.56 Ω
4	19	190m A	6	0.30	1.58 Ω
5	10	100m A	3	0.15	1.5Ω

Table 1: Table of ammeter and voltmeter readings: Mean R=1.56

The average resistance is

$$R = 1.56$$

The practical measure of the length of the resistance wire used in the experiment is: 28 cm

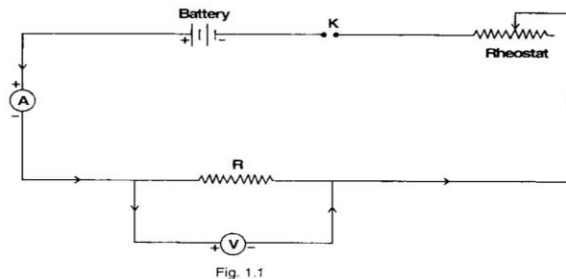
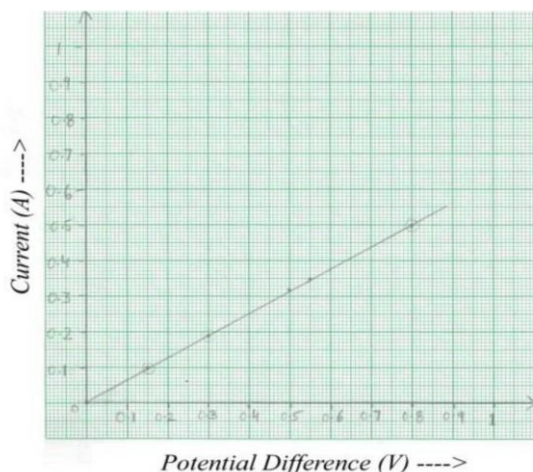


Fig. 1.1

The graph between voltage and current:



Scale: X-axis: 1 cm = 0.1 volts of potential difference
 Y axis: 1 cm = 0.1 amp
 The graph is a straight line .

4. Results

It was found that the ratio V / I is constant, and then the voltage and current relationship was established and they are in direct proportion. In other words, Ohm's law has been proven: The law is verified .

Find the unknown resistance per cm of the specified wire

$$5.57 = x \cdot 10^{-2} \text{ ohms per centimeter}$$

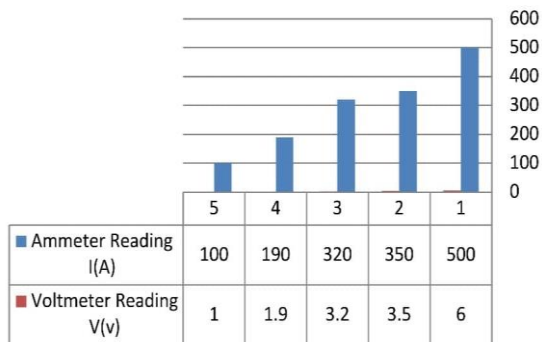
Possible sources of error in real-world experience:

The variable resistor may have a high resistance .

The device screws may not be properly installed .

The result of applying Ohm's law in the PHET simulation

**Potential difference&Current
 in the simulation**



Note that applied computing

Parameters are used corresponding to those used in the real-world experiment, and these converge with results previously observed in the remote laboratory .

Although laboratory experiments play a crucial role in engineering education, they contribute strongly to the development of skills important for professional practice. This paper addresses the researcher's understanding gap between simulations and remote laboratories. which we are developing at the University of Tobruk, thus evaluating the researcher's perceptions taking into account simulations and remote laboratory results .

Through this experiment, quantitative data were analyzed to find out the difference and the extent of differences between the simulation software resources and the type of practical data in the laboratory [19-25] .

Preliminary results indicate that a large number of results are in almost complete agreement with actual practical results .

5. Discussion and Conclusions

Researchers learn about the mathematical functions and equations that underlie typical physical phenomena. The content of the curriculum and its courses in the departments of Applied Physics and Electromagnetic and Electronic Engineering covers the topics of classical mechanics (kinetics, Newton's laws, energy, work, and renewable energy), electricity and circuits (Coulomb force, electric field, electric current, and electric circuits), and electronic). The overall goal of the applied science departments is to develop knowledge and understanding of these topics to mobilize and apply them to actual engineering contexts. We have worked on introducing the PhET program and used it to achieve various goals, including developing concepts and working on designing accurate practical systems [26].

As we noticed in the tables that presented the results and the resources used, in addition to the period in which the researcher had to hand over the readings as a result of this task and showed the extent of accuracy and closeness between the far lab and the simulation lab .

We conclude that different resources (remote laboratory, simulation, and practical laboratory) allow the researcher to practice some experimental skills differently, but to make the most of them, he needs to understand the main differences in the type of measurements collected during his use. The experiment dealt with in this study deals with the researcher's perception of the difference between simulation and remote laboratories. For the researcher to understand the difference between simulation and remote laboratories and the type of different results that were obtained with each of them, the research methodology adopted in this study is quantitative and qualitative [27-31], where each case is represented differently with the application of simulation adopted in this study .We have followed the method based on a set of questions that have been validated, and used in the approved application of the simulation (30).

6. Recommendations and future studies

The current hardship we live in is witnessing many transformations towards the use of technologies in education, and this led to the development of the educational process and achieved the goals of education more effectively and led to improving the quality of education by employing these tools in the educational process, and among those tools were the virtual laboratories, which have a role greatly improves the skills of researchers due to its ability to facilitate the method of learning through simulation of the real laboratory in its functions, and aims to develop scientific thinking and provide the learner with practical experiences through virtual reality technology. Virtual laboratories are considered the main pillar in e-learning in the field Practical and applied the virtual lab is considered one of the innovations of modern technology, which is an extension of the development of electronic simulation systems). (Virtual laboratories also work to provide ideal solutions to the problems that the traditional laboratory suffers from. Virtual experiments transcend the limits of time and space, and they can overcome the problem of possibilities in addition to providing the elements of safety and security.) They can also provide the opportunity for learners to simulate costly experiments. or dangerous ones, as it allows them to return them, and this is difficult to apply in real laboratories). The virtual laboratory largely simulates the traditional laboratory in its functions and events. When the researcher visits one of the virtual laboratory sites on the Internet, he can practice the laboratory activities that usually

occur in the real traditional laboratory, through the use of simulated (virtual) three-dimensional devices and materials. It is as if it exists in a real laboratory. Many studies and research have proven the effectiveness of using virtual laboratories in education as a study (we refer here to the effectiveness of using virtual laboratories in the collection and development of practical skills, as we have noticed in the results presented through the practical experience of measuring the resistance of a wire on a unit length of the wire (which concluded the effectiveness of virtual laboratories in acquiring the skills of laboratory experiments in the real laboratory).

(Which also concluded the effectiveness of the virtual laboratory in the collection of different levels of researchers. à

We strongly recommend the need to use of virtual laboratories in education, as we have the necessary competencies to operate them and the ability to use them effectively in the educational process. We also emphasize through this paper the importance of virtual laboratories and their role in developing many skills and a great impact on scientific thinking. And collection.

The use of physical, engineering, and even medical virtual laboratories in the achievement and science fiction of Libyan university students, and in the applied side in particular, we believe in their ability to memorize this information and store it in the researchers' memory in a better and more effective way in practical applications.

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UV-derived spectrophotometry (*Advantages – disadvantages*)

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ABSTRACT

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Pierre Bouygués discovered his law, an empirical relationship that relates the absorption of light to the properties of the material through which the light passes. Multicomponent analysis works to determine the mutual quantitative and qualitative arrangement using the spectra, and because their ranges have not been resolved yet, it is possible to use the first or highest derivatives according to the wavelengths, and this is evidence that the derivation of the absorption spectra increases the selectivity. The conversion of the ordinary spectrum into a derivative depends on the concentration of the substance when applying Beer's law to the primary spectrum. In this paper, we address the advantages and Negatives of derivative spectroscopy.

Keywords: Spectra, spectral analysis, wavelength, order absorption spectrum, Derivative spectrometry, and medical derivation.

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1. INTRODUCTION

The spectrophotometry technique is applied at the slope of the spectrum It is the rate of change of absorption as a function of wavelength (zero or fundamental spectrum) [1]. In the spectrum derived for quantitative measurement, we note the intensity of a small band (during the analysis of the interfering band) that is obscured by a parametric overlapping band [2], known as the zero-order spectrum, which is the fundamental spectrum, and determines the relationship of absorption against wavelength. The digital data of the first derivative spectrum can be obtained from the graph between the spectral slope and the wavelength, and the second derivative of the first ... etc. Thus, the derived spectra became a more specific, simple, fast, and applicable method; Because it increases selectivity by eliminating Spectral interferences [2].

2. Overview

From the background in ultraviolet science, we know that ultraviolet radiation was detected when silver salts became darker after exposure to sunlight. In 1801, physicist John Wilhelm Ritter noted that invisible rays, whose wavelength is shorter than violet, the far end of the visible spectrum, are particularly successful at darkening chlorinated silver paper [3]. It is called ultraviolet radiation of less than 200 nanometers and it is known that the air absorbs it, and the physicist Victor Schumann confirmed that it was discovered in 1893. Ultraviolet radiation is classified into several wavelengths overlapping each other according to the ISO standard project (ISO-DIS-21348) in determining solar radiation [4]. In this project, each wave has a distinctive name,

symbol, nanometer wavelength, and then the amount of energy per photon. The system starts with long ultraviolet, called UVA black light, then near wave NUV, then medium wave or UVB B, medium-wave MUV, then short wave C or UVC, then far FUV, then vacuum, and finally Extreme EUV .

Oxygen can absorb these wavelengths, so industrial processes that need these wavelengths must be carried out in an atmosphere completely devoid of oxygen, and pure nitrogen is generally used here to prevent the need for vacuum chambers [5].

A spectrophotometer was used Spectroscopy studies ultraviolet and visible light, as well as chemistry to analyze chemical structures, especially conjugate systems. UV rays can measure visible light to determine the presence of a certain amount of radiation. Ultraviolet rays are also used for metal and gemstone analysis, detection, and documentation work. Raw materials are also studied by looking under visible light, but the degree of glow is different under ultraviolet light, or even different between short and long ultraviolet light [6]. We also found that UV fluorescent dyes have many uses such as biochemistry and forensics, and there's green fluorescent protein (GFP), which genetics uses as a chemical marker [7]. UV/Vis spectroscopy is a type of spectrometer that is classified under absorption spectroscopy, which occurs in the ultraviolet spectrum and the visible spectrum. This means that this spectrometer uses light in both the visible and near regions of the ultraviolet spectrum and even parts of the near-infrared (NIR) spectrum. Absorption or reflection in the visual field affects the perception of color on chemicals, as electronic transitions occur as a result of the effect of electromagnetic radiation. This spectroscopy is concerned with electronic transitions from the ground state to the excited state and is thus complementary to fluorescence spectroscopy, which studies the fluorescence resulting from the transition from the excited to the ground states. In visible and ultraviolet

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spectroscopy, molecules are exposed to electromagnetic radiation in the visible and ultraviolet fields, which leads to irritation and excitation of valence electrons (such as p or d electrons in the outer orbits) [8]. That is, they gain energy and an electronic transition occurs within the energy levels of the molecule. The energy of the photon that is absorbed for this transition to occur corresponds to the energy difference between the energy levels in which the transition takes place. That energy is calculated from the equation:

$$E = h \cdot \nu = \frac{h \cdot c}{\lambda} \quad (1)$$

where: E energy, h Planck's constant, ν frequency .

From here, the absorption spectrum can be defined as the opposite of the emission spectrum, and the absorption spectrum occurs when light passes from a hot source, which produces a continuous spectrum, and through a cooler gas [9]. The absorption spectrum of the material shows the part of the incident electromagnetic radiation, which is absorbed by the material through a range of frequencies. An example of the absorption spectrum is that it is used to identify the elements present in gases or liquids, as all chemical elements contain absorption lines with specific wavelengths and different ones that correspond to the differences between the energy levels in the orbits of the element, and this method is used to deduce the presence of elements in gaseous bodies. that cannot be measured directly .

3. Previous studies

Previous studies focused on the theoretical aspects and tools associated with spectrophotometry-derived. It is known that the ideal absorption spectra and their derivatives are of the first to the sixth order The intensity and width of the peaks are affected by their relative status The position of the bands produced by the analyzed materials and thus the quality of the derived spectra Obtained by choosing the order of the derivative and the measurement technique .Then the dependence of the parameters of the device used on the trajectory of the derived curves [10].

described. The numerical differentiation technique is one of the most important methods for obtaining derivatives. So, the number is supported by the points of the spectrum and the degree of agreement of the polynomials on their smoothness and the differentiation of the spectra. Also, there are possibilities for improving the selectivity and sensitivity when measuring the derivative spectrum .This technique is applied and introduced to select analytes whether they are inorganic or organic. The derivative spectrometry is associated with the emergence of Spectrophotometers used by researchers to record the derived spectra [11]. At first, the derivatives were first-order important. But with the development of devices especially Photometers connected to computers, showing higher level derivatives, which gave more interesting possibilities from the point of view of Chemical analysis The result was the differentiation of analog (electronic) and digital A suitable tool when high-level derivatives are required. This success prompted the scientists to use the Savitzky-Golay algorithm [12], because it is the most important numerical algorithm for obtaining derivatives Spectra . Spectral technology has caused many specificities compared to classical spectrophotometry. Generally, by differentiating a zero-order spectrum it is possible to obtain sequential derived spectra that are separated from overlapping vertices, increasing the selectivity without deletion analytics. Thus, an increase in selection sensitivity is achieved with increasing order of derivatives .got up. G. Talsky 1994 developed this technique with additions to measurement theory [13], which most researchers relied on in their studies and gave very accurate results when measuring the derived optical spectrum. Visible and ultraviolet spectrophotometry deals with the absorption spectra

produced by an electron or when it occurs Transitions between energy states in a molecule. When this transformation is accompanied by absorption The amount of energy in the UV-VIS region that is represented in the absorption curve depends on the intensity of the radiation waveform (wavelength .The value of the transition energy is related to the location of the band in the ultraviolet or visible light region, it is usually described as the maximum intensity of the band with the probability of electron transfer from the ground state to the excited state and the molar absorbance is the associated band parameter [14].

Moving on. These parameters characterize the system qualitatively and quantitatively in classical molecular spectroscopy, and this proves that the molar electron gives transitions that are not as narrow as in atomic transitions. This can be explained by the interference of ground state energy, oscillation energy, and rotational energy as well as the interaction of substance particles with the solvent when treating liquids [15]. Thus, the bandwidth parameter is important for finding the peak width and thus, in the spectral measurement derived, is characterized as the so-called half-width (L), that is, the width of the peak at half its height When measuring the UV-VIS-derived spectrophotometer, specifically the absorption curve, where Perfect peaks and their derivatives It is similar to the Gaussian curve, and the Lorentzian curve, the central part will be narrow from the peak or intended [16]. Practically the central part of the peaks is narrowed It is more pronounced in the case of Lorentz-type peak derivatives. We will often find that in the advancing peaks, the magnitude of the derived signal decreases with increasing order of the derivatives. However, the Lorentz-type peak derivatives have higher values except for the first derivative [17].

In most research studies, the ratio between the maximum peaks of Lorentzian derivatives can be calculated as Those of the Gaussian type where the first, second, third, fourth, and fifth derivatives, respectively. And calculating the values of the required peaks by applying functional relations, when obtaining the ideal derivatives with a specific zeroing, As well as the setting and values of the maximum and minimum limits. Such operations give an idea of Relationships that occur between the base spectrum and spectra that are set by differentiation. Spectra of variable parameters can be mapped using statistical software such as Microsoft Excel [18]. Then the curves are plotted with arbitrary units and the use of arithmetic factors that connect the wavelengths of the spectra and the distance between the spectra points. In other words, the coefficients at each stage are meant to be several points in the spectrum and each of them contributes to the evaluation of the units used So that ranges can be set that differ from each other by one unit [19], which means one step to calculate the derived range or curve. As a result of this coefficient applied, the derived values are Calculated from functional relationships, and those assigned from identical increments are given the Same results. For simplicity, the intensity of the simulation spectra can be assumed to be equal to one [20]. Comparing the amplitude values which is the difference between themax and The minimum value of the curve for a derivative in the first to sixth order indicates that in broad spectra the derivative decreases systematically with an increase in the order of the derivative, for the Gaussian (PG) and Lorentzian (PL) peak types .Also, the sharp values in the course of these changes will be different with an increase in the order of its derivative, and it will be noted the lower value of the derivative first means getting the lower bound of the second derivative and then comes Increases to exceed the Lorentzian peak value equal to the base value for adomain .It can be concluded that by using a spectrometer derived for flat spectra there is therefore no increase Note the measured signal, in contrast to sharp spectra, where the post-differentiation signal is

measured to be greater than the baseline signal [21]. Ideal Gaussian or Lorentzian curves are often the same only in wavenumber because they lose symmetry in the wavelength scale. The researcher should be careful in choosing this coefficient as well as the unit of measurement. When comparing the recorded spectra as a function of wavelength and converting them to a function of wavenumber, which requires a procedure simulated with ideal spectra and then finding the difference in the verification data to find out the validity of the differential algorithm used [22]. The goal of obtaining accurate data is discrimination.

The real spectrum whose range is similar to the simulation [23]. As in the classical spectral measurement, we note that the most important properties of the derivative spectral measurement are that it depends on the concentration of the derived value, through the Lambert-Beer law and determining

Wavelength [24]. It is believed that standard conditions are a measure of sensitivity in methods of applying the derivative Spectrophotometry was measured by measuring the molar absorbance as is done in the case of classical spectrophotometry. When measuring the derivative value and choosing the minimum wavelengths, the measurement is performed at those wavelengths at which the derived spectra for specific components are subject to zeroing [25]. So, the relationship between the signal value and the half-width of the peak L is a specific property of the derived spectroscopy [26]. Spectroscopy is one of the effective methods of sensitivity and selectivity. Compared to the classical derivative based on spectrometry just as in the color scheme. It can be said that the measurement is a true result, as differentiation allows obtaining a larger amount of information contained in the primary absorption spectrum. Due to this, the differences in the position of the peaks and also in the peak half-width may be taken advantage of, and in a more precise sense, we conclude that in a simple measurement, it is impossible to determine the components of the mixture. In practice, when performing spectra differentiation, we find that the first derivative spectra to determine substance B in the presence of substance A is the result of zeroing the range derivative of substance A. Where the derivative values for mixture and substance B are equal at a given wavelength, this explains that the derivative of substance A crosses the zero line, and this measurement is called the zero-crossing technique [27]. An increase in the order of the derivative flattens the band B.

The derivative and the increment of the A derivative signal. The researchers found that in most samples, the value of the signal in the derived spectral measurement depends precisely on the basic spectrum shape [28]. Spectra with sharp peaks are preferred because the signal values are higher. It increases after differentiation with the order of the derivative, in contrast to spectra of flat peaks, at which the signal dips. This means the ratio of the signals is inversely proportional to the ratio of the peak-to-half-width in the order of equal derivative. The reliefs appearing on each small sharp peak interspersed with another flat peak represent an intense band of the overall fundamental spectrum. The value of the sharp peak is differential, which is several times greater than that of the broad peak. Thus, the value derived decreases by half the width of a given spectrum [29]. In the case of spectra with similar half-widths, the derived value of the material and wavelength number of perturbations can be determined such that they cross the derivative of the zero-line substance means that it reaches a zero value and therefore does not affect the determined derived value of the material. It can also be said that derivative value measurement techniques work to produce the derivative spectrum of any order of differentiation zero where the (basic) spectrum arrangement of a mixture of components. Spectrum differentiation can be performed in different ways, including analog or digital. Regardless of the

method of differentiation, the results can be graphically modified on paper or paper recorded in the computer's memory [30].

Generally, derived values are found in three ways. The determination may be graphic or numerical. Fee metering consists of recording on paper with an XY recording device or the plotter, so the result is a derivative spectrum and a zero line [31]. The numerical measurement of the derived values is performed through a readout A value derived at a given wavelength or wavenumber from a set of points or wavelength of a derived value. This is how this group is obtained as a result of spectrum differentiation.

Using an appropriate numerical algorithm to obtain the derivatives. When looking at the derived spectrum, on a computer screen linked to a light spectrophotometer, the values derived at changing wavelengths are determined step by step to be precise. If there are no points at a particular wavelength, then, it must be known point values before and after waveforms are determined, as well as possible.

Calculate the derived values by connecting the nearest point with a straight line or many limits. Such a solution should be achieved in software by amplifying part of the spectrum. The graphical and numerical measurements of the derived value differ from each other. The absorbance value cannot be measured in a conventional spectrophotometer and thus can be performed using a spectrophotometer.

The optical spectrum can be measured based on recorded data and taking into account the contrasting absorption spectrum, which is the zero-crossing technique [32], in measuring the derivative where the value at the wavelength or the number of waves, and the derivative that is obtained accepts the value of zero, that is, it crosses the zero line. As for the derivative of the absorption spectrum, it can be obtained in the template by one of two methods, the first by electronic analogy between the detector output signal, and the second by digital differentiation, where the differentiation of absorption spectrum is recorded in computer memory. It is noted in analog technology, that there is an appropriate electronic circuit known as the derived unit, which is connected between the spectrophotometers or the detector outputs and inputs are often digitally recorded. The wavelength in the derivative is associated with a time parameter, and it is usually of a fixed value [33]. The derivative unit amplifies the signal by reducing noise at the same time. So, the derivative is of the order of n . A means of obtaining spectra in the analog technique with zero order omitted for spectra derived from the lower orders. The order of the derivative depends on the number of derivation circles.

The researchers also noted that the derivative can be obtained from the visible and ultraviolet spectrophotometry by applying Savitzky-Golay methods so that the numerical difference A cause of noise affecting the derivative and shape of the spectrum.

4. Evolved analog spectroscopy.

When this science arose, complications were made to produce the derivative spectrum during UV-Vis spectroscopy. The method was not encouraging during practice. With the invention of the first analog spectrometer by Singleton and Cooler, and increasing the selectivity by deriving the digital data set removing the spectral overlaps, and using computers, the derived spectra became a more specific, simple, speedy, and portable method in laboratories, research centers, and industrial institutions [34]. In it, the mathematical derivative of the absorbance concerning the wavelength of radiation is calculated, electronically or using a computer. Thus, the derived spectroscopy technique became a process of distinguishing spectra mainly in infrared, ultraviolet-visible absorption, and

fluorescence spectroscopy, and among the derived methods used were spectral differentiation, improvement of spectral resolution, and quantitative analysis. It is necessary to identify the different differences between these methods, for example, spectral differentiation. It is a qualitative method for the spectrum that distinguishes small differences between similar spectra, and when applying the method of improving spectral resolution. The overlapping spectral bands are resolved to estimate the number of bands and their wavelengths. In the case of multicomponent quantitative analysis, the background absorption can be corrected as the overlapping bands [35]. By studying the vital characteristics of the derivation process, we find that there is a need to stabilize the broad bands, especially in the acute groups. For the zero, first, and high derivatives in the derivative spectroscopy, secondary spectral features can be detected and measured, which enhances the distinctive spectral details and similar spectra and follows up the slight changes in the spectrum, which is useful in quantitative analysis to measure the concentration of a substance whose peak is obscured by a peak overlapping with a component of the sample. Practically, the perpendicular distance between the adjacent maximum and minimum value of the first derivative can be treated as a measure of the intensity of the analysis, which helps to estimate the density of the material. When the band is due to the interfering device, it is possible to measure the derived spectra [36]. From experience, we find that the values of the derivative spectra are more organized than the original spectra because the number of peaks continues and increases with the increase in the order of the derivative. In the first order, the original band is divided into two parts, then the original band is divided into three, thus the number of peaks in an "n" spectrum will be:

$$N = (n + 1) \quad (2)$$

The zero-order spectrum, or what is known as the basic spectrum, is given by a relationship between absorption and wavelength, then the derivative of the first order, and it is calculated through the ratio between the change of absorbance and wavelength, and in this way, the derivative starts from the first order until it ends at zero. It passes through zero at the same wavelength as the absorption band [37]. Therefore, the bands, whether positive or negative, have maximum and minimum wavelengths of the same wavelengths as the inflection points in the absorption band. This means that the bipolar function is characteristic of all derivatives of the system. The spectrum is calculated from the first order, then the second spectrum in the form of a spectrum curve plot against wavelength. The most distinctive of, them is characterized by the presence of a negative band with a minimum of the same wavelength as the maximum on the zero scales. The early techniques used in UV-visible spectrophotometers have been replaced by other mathematical techniques and are characterized by the ease of calculating the derived spectra through various parameters based on smoothing, signal ratio optimization, and noise detection [38].

5. CONCLUSION:

The derived spectrum shows better resolution for the overlapping bands than the basic spectrum and may allow precise determination of the maximum individual bands. Also, in the case of the small wavelength range, in the presence of two or more overlapping peaks, absorption bands can be identified. thus, eliminating the background effect in the derived spectra. It is a simple, effective, and repeatable method. This confirms that selectivity improves sensitivity and specificity, and it is a faster technique than other classical methods. One of the drawbacks of the derivative spectral analysis is that it depends on automated parameters such as scanning speed, slit width, and its evaluation

in the conditions of automatic recording of the zero-order spectrum, which affects the spectra derived from it. Derivative spectral analysis is facilitated so the researcher can obtain the necessary information from Atyaf's different materials. It is considered The derivative spectral analysis is one of the fastest and most accurate automated methods, taking into account the drawbacks that we mentioned during this study .

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Separation of Crude Oil and Its Derivatives Spilled In Seawater by Using

Commiphora Myrrha and Coal Fly Ash

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ABSTRACT

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This investigation delved into the comprehensive assessment of a composite amalgam featuring hybrid nanoparticles composed of CoFe_2O_4 , an extract from Commiphora Myrrha, and Coal Fly Ash. The primary objective of this study was to ascertain the potency of this composite in addressing the intricate challenge of marine oil spill mitigation, particularly within the context of pervasive environmental contamination. The synthesis of the hybrid nanoparticles was executed at Sebha University, with the remaining components being procured from established commercial sources. The meticulous characterization of these constituents was conducted employing advanced analytical techniques, namely X-ray diffraction spectroscopy (XRD) and infrared absorption spectroscopy (FTIR). The empirical findings gleaned from the experimental investigation conspicuously spotlight the superior efficacy achieved through the strategic employment of hybrid NPs, specifically the CoFe_2O_4 nanoparticles combined with Commiphora Myrrha extract, at a compositional ratio of 20:80. Under these conditions, an appreciable oil removal efficiency of 30.7% was realized, demonstrating the pronounced influence of the amalgamation on the mitigation process. Notably, this efficacy was realized at a concentration of 0.06 g, underscoring the optimal operational parameter within this experimental framework. Remarkably, the pinnacle of success was encountered when hybrid NPs were synergistically combined with coal fly ash, configuring a proportion of 30:70. This synergistic alliance yielded a conspicuously impressive oil removal efficiency of 69.7% under identical concentration conditions of 0.06 g. This outcome significantly underscores the strategic potential of the composite in the context of marine oil spill remediation. The ramifications of these findings are notable, as they contribute to the advancement of knowledge in the realm of environmental contamination management. Furthermore, the demonstrated efficacy of this composite prompts further inquiry into refining and optimizing the proportionality of its constituents and their application methodologies. It is recommended that subsequent studies delve into the mechanisms underlying this composite's performance enhancement, paving the way for the potential integration of this innovation into practical strategies aimed at alleviating the detrimental effects of marine oil spills on aquatic ecosystems.

Keywords: Nanoparticles; Commiphora Myrrha; Coal fly ash; Oil spills removal; waste materials; Hybrid Nanoparticles.

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1. INTRODUCTION

Accidental oil spills stemming from incidents involving the dispersion of petroleum substances, often originating from maritime vessel mishaps, have been recognized as a recurring environmental challenge, predominantly affecting marine environments. Noteworthy instances of such ecological perturbations include the al-Kuwait oil conflagration of 1991, wherein a substantial volume of oil was discharged into seawaters [1,2]. Similarly, the Deep-water Horizon catastrophe in 2010, situated within the expansive expanse of the Gulf of Mexico,

precipitated the release of an estimated 206 million gallons of petroleum derivatives into the aquatic milieu [3-5]. These incidents, emblematic of a broader pattern, underscore the critical need for enhancing and optimizing the efficacy of oil spill remediation methodologies; given that global cumulative oil spillage has reached staggering proportions, exceeding 400,000 tons [6,7].

These incidents not only pose immediate threats to marine life but also pose long-term ecological and socio-economic consequences. The dispersal of oil in water bodies engenders deleterious impacts

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on aquatic ecosystems, manifesting as habitat degradation, toxicological ramifications, and disruptions in the food chain [8,9]. Furthermore, the encroachment of oil slicks onto coastlines can adversely impact local economies, ranging from tourism and fisheries to shoreline real estate. Hence, the imperative to evolve and augment the methodologies employed for oil spill mitigation is underscored by both environmental and economic considerations [10].

One of the key challenges in seawater pollution is the high viscosity and strong adhesion properties of crude oil, which can lead to significant contamination of adsorbents, separation materials, or even their deactivation. In recent years, superhydrophilic materials have been designed based on a combination of their surface morphology and affinity with water to effectively separate oil from water while possessing excellent oil-repellent properties [11–13]. However, most of these materials are capable of only repelling light oils or model oils and are still susceptible to contamination by crude oil residues. Their superior water absorption and retention capabilities distinguish them from other hydrophilic materials.

Among these materials, Nano cellulose extracted from natural plant cell walls has garnered significant attention. The outstanding oil-repellent property of Nano cellulose arises from its unique chemical composition, in which hydrophilic groups are closely and densely linked to the surface of the nanomaterials. This intrinsic property facilitates efficient oil-water separation. The development and utilization of these materials are pivotal in addressing the complex challenges associated with marine oil pollution. The multifaceted interactions between oil and water, compounded by the intricate physicochemical attributes of the marine environment, necessitate innovative and adaptive solutions. In light of these considerations, Nano cellulose emerges as a promising candidate for mitigating oil spills and reducing their detrimental effects [14–17].

Also, the utilization of Commiphora Myrrha [18] in the context of oil separation from seawater represents a notable advancement in environmental remediation strategies. Commiphora Myrrha, a natural material with hydrophilic and adsorptive characteristics, has demonstrated considerable potential as an adsorbent for oil removal due to its inherent affinity for hydrophobic substances. The resin's complex composition, including terpenoids, phenolic compounds, and polysaccharides, contributes to its efficient oil-absorbing properties [19]. Through a combination of physical interactions, such as adsorption and cohesion, Commiphora Myrrha can effectively capture and encapsulate oil molecules, resulting in the separation of crude oil from the aqueous environment. Moreover, its biodegradability and eco-friendly nature make it a compelling candidate for sustainable oil spill mitigation efforts. The application of Commiphora Myrrha in oil separation signifies a harmonious integration of natural materials and scientific innovation, presenting a viable pathway toward addressing the challenges posed by oil contamination in marine ecosystems [20–22].

Efforts geared towards the amelioration of oil spillage necessitate a holistic approach, encompassing the development of innovative technologies for containment, recovery, and remediation. Novel materials and strategies, such as the hybrid nanoparticles comprised of CoFe₂O₄, Commiphora Myrrha, and Coal Fly Ash explored in this study, stand as emblematic examples of contemporary endeavors aimed at addressing this multifaceted predicament [20]. By deepening our comprehension of the intricate physicochemical interplays dictating the behavior of oil-water interfaces and capitalizing on the advancements in novel materials, the feasibility arises to conceptualize and implement interventions characterized by markedly enhanced efficacy in the purification of oil-contaminated aqueous ecosystems. Such advancements stem from a comprehensive grasp of the intermolecular forces, adsorption phenomena, and molecular arrangements that underlie these interfaces [23–25]. Leveraging cutting-edge materials, with tailored properties and functionalities, enables the strategic design of sorbents, dispersants, and emulsifiers that optimize the separation, dispersion, and degradation of oil pollutants. These interventions, rooted in scientific insights, pave the way for more efficient and environmentally responsible approaches to tackling the persistent challenge of oil contamination in aquatic environments [26–28].

Moreover, the convergence of fundamental understanding and innovative materials holds the potential to drive the development of sustainable technologies with a broader spectrum of applications, extending beyond oil spill remediation to encompass diverse environmental and industrial contexts.

By synergistically combining hybrid nanoparticles composed of CoFe₂O₄, Commiphora Myrrha extract, and Coal Fly Ash into a nanostructured composite, a novel avenue emerges for addressing marine oil spills. This innovative approach capitalizes on the distinctive properties of each constituent to achieve efficient oil-water separation. The utilization of such a composite holds promise as a potent solution for mitigating the intricate challenges posed by oil leakage in marine environments. The integration of CoFe₂O₄ nanoparticles serves to enhance the separation process through their responsive magnetic properties, allowing for facilitated manipulation and recovery of the composite from the aqueous medium. Commiphora Myrrha extract, characterized by its hydrophilic and adsorptive attributes, contributes to the composite's oil-absorbing capacity. Furthermore, the inclusion of Coal Fly Ash, renowned for its adsorption and affinity for hydrophobic substances, synergistically augments the composite's overall oil removal efficiency.

In consideration of the aforementioned attributes delineating the distinctive qualities of spinel magnetic nanoparticles, rendering them highly auspicious within the realm of water technology for diverse contaminant species, the present investigation is directed towards the attainment of the following objectives:

Investigation of the feasibility of the employment of a hybrid absorbent composite (incorporating spinel magnetic nanoparticles in conjunction with Commiphora Myrrha and spinel magnetic nanoparticles in tandem with coal ash), with the principal objective of effecting the elimination of crude oil and its derivatives from aqueous mediums.

Attainment of a heightened echelon of oil adsorption efficacy through the utilization of a novel and economically viable absorbent material characterized by diminished cost and augmented operational efficiency.

2. Experimental Part

The oil removal tests were performed as described previously in the literature [29–31]. In this test (30 ml) of seawater, 1 ml of crude oil was injected, nanomaterial was added with the addition of, and then it was weighed and left for 30 minutes:

$$GOR = \frac{\text{weight of baker with sample (Oil + Powder + Water)} - \text{weight of baker after construction}}{\text{total weight of Powder + Oil}}$$

$$\text{Oil removal percentage} = (1 - GOR) \times 100$$

Where GOR is Gravimetric Oil Removal



Figure 1. Process of crude oil removal from seawater using Nano magnetite (a) mixture of crude oil with CFA-CFO in seawater, (b) attraction of crude oil with CFA-CFO in seawater by magnetite.

3. Results and discussion

3.1. Chemical composition of Commiphora Myrrha (CM), Cobalt Ferrite Oxide (CFO) and Coal fly ash (CFA)

Table 1 presents a comprehensive depiction of the chemical constituents inherent to Commiphora Myrrha (CM), Cobalt Ferrite Oxide (CFO), and Coal Fly Ash (CFA), as discerned through the analytical methodology of X-ray fluorescence (XRF). The outcomes of this analysis underscore that the triad of scrutinized samples predominantly exhibits iron (Fe) concentrations of 9.02%, 43.6%, and 0.893%, respectively. Furthermore, appreciable fluctuations in cobalt (Co) contents are evident, with percentages of 1.06%, 15.6%, and 0.0375% characterizing the respective constituents. Additionally, minor proportions of silica (Si) are identified, denoting 32.1%, 0.522%, and 2.82% in the designated order. Alongside these primary components, a range of diverse constituents such as sulfur (S), calcium (Ca), and nickel (Ni) are also present in varying quantities.

Table.1 Chemical Composition of CM, CFO, and CFA.

Compounds Formula	CM	CFO	Concentration
			(%) CFA
Si	32.1	0.522	2.82
Al	16.0	0.300	2.02
Fe	9.02	43.6	0.893
Ca	8.72	0.123	68.0
Co	1.06	15.6	0.0375
S	5.82	16.1	1.72
K	5.06	-	11.0
Cl	4.53	-	1.84
Ti	1.44	-	0.0877
Ni	1.89	0.102	0.136

3.2. Infrared Spectrum Results

3.2.1. Infrared spectrum of the Cobalt Ferrite Oxide (CFO)

The spectroscopic data acquired for the compound with the molecular composition of Cobalt Ferrite Oxide (CFO) reveals significant features in its infrared spectra. Evident within this spectral profile is a pronounced broad band manifesting at 3490 cm^{-1} , corresponding to the presence of water molecules. Furthermore, the identical spectrum exhibits a distinct band at 2600 cm^{-1} , indicative of the vibrational frequency (ν) attributed to the hydrogen-carbon double bond ($\nu\text{HC}=\text{O}$) inherent to the aldehyde moiety. In tandem, the infrared spectrum of the same compound evinces discernible bands positioned at 1480 cm^{-1} and 1625 cm^{-1} , which can be ascribed respectively to the characteristic vibrations of carbon-carbon double bonds ($\nu\text{C}=\text{C}$, aromatic) and carboxylic acid functional groups ($\nu\text{-COOH}$). The comprehensive infrared spectral presentation is visually depicted in Figure 2 for reference and analysis.

Table.2 Infrared spectral data of Cobalt Ferrite Oxide (CFO).

νOH	$\nu\text{C-H}$	$\nu\text{C}=\text{C}$	$\nu\text{HC}=\text{O}$	$\nu\text{-COOH}$	$\nu\text{Fe-O}$	$\nu\text{Co-O}$
3750 cm^{-1}	2950 cm^{-1}	1480 cm^{-1}	2600 cm^{-1}	1625 cm^{-1}	960 cm^{-1}	670 cm^{-1}

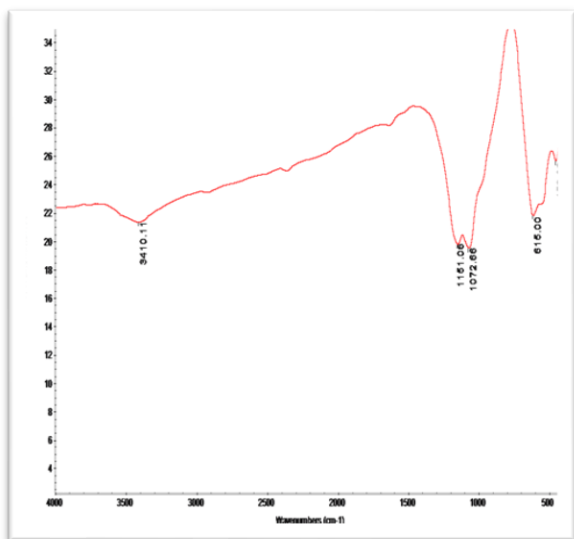


Figure .2. Infrared spectrum of the Nano Cobalt Ferrite Oxide (CFO).

3.2.2. Infrared spectrum of the *Commiphora Myrrha* (CM)

The spectral analysis conducted on *Commiphora Myrrha* unveils pertinent characteristics evident in its infrared spectra. A pronounced and broad absorption band is observed at 2966 cm⁻¹, which can be ascribed to the presence of water molecules. Similarly, within the same spectral context, a distinct band emerges at 1701 cm⁻¹, attributed to the vibrational frequency (ν) associated with the carbonyl functional group (ν C=O). Additional spectral features include a discernible band located at 1468 cm⁻¹, corresponding to the vibrational frequency of carbon-carbon double bonds (ν C=C) within the aromatic moiety. Concurrently, an observable band positioned at 1386 cm⁻¹ is attributed to the vibrational mode (ν) inherent to carboxylic acid functional groups (ν COOH). Further insights are garnered from the presence of a band at 1272 cm⁻¹ within the same spectrum, elucidating the occurrence of the hydroxyl group's (C-OH) vibrational mode.

Table.3 Infrared spectral data of *Commiphora Myrrha* (CM).

ν OH(H ₂ O)	ν C=O	ν C=C	ν COOH	ν C-OH
2966 cm ⁻¹	1701 cm ⁻¹	1468 cm ⁻¹	1386 cm ⁻¹	1272 cm ⁻¹

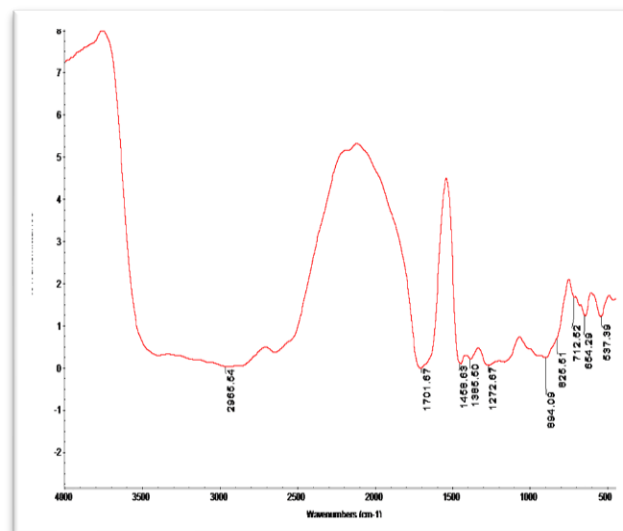


Figure 3. Infrared spectrum of the *Commiphora Myrrha* (CM).

3.2.3. Infrared spectrum of the Coal fly ash (CFA)

The infrared spectroscopic outcomes obtained from the analysis of Coal Fly Ash have been compiled and presented in Table 4. Within the recorded spectra of Coal Fly Ash, discernible features are apparent. A characteristic band at 3437 cm⁻¹ is observed, indicative of water molecules present in a hydrated state. Concurrently, these spectra manifest a prominent band at 2621 cm⁻¹, corresponding to the vibrational frequency (ν) attributed to the amino group (ν NH₂). Furthermore, a distinctive band is evident at 2967 cm⁻¹ within the same spectra, arising from the vibrational mode of aliphatic carbon-hydrogen bonds (ν C-H group). Similarly, the infrared spectrum of the aforementioned compound unveils an additional band located at 1446 cm⁻¹, which can be attributed to the vibrational frequency of carbon-carbon double bonds (ν C=C, aromatic). Moreover, the infrared spectrum depicts the presence of two distinct bands, as illustrated in Figure 4, signifying the vibrational modes of aromatic carbon-hydrogen bonds (ν C-H group, aromatic) and carbon-oxygen-hydrogen bonds (ν C-OH).

Table.4 Infrared spectral data of Coal fly ash (CFA).

ν OH(H ₂ O)	ν NH ₂	ν C=C	ν C-H	ν C-OH
3437 cm ⁻¹	2621 cm ⁻¹	1446 cm ⁻¹	2967 cm ⁻¹	1071 cm ⁻¹

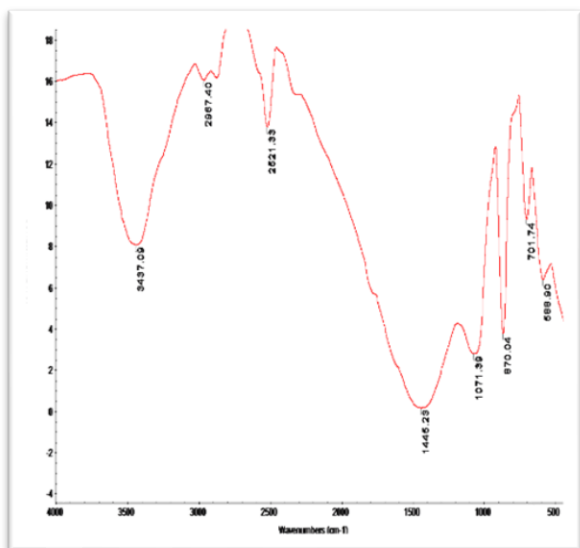


Figure 4. Infrared spectrum of the Coal fly ash (CFA).

3.3. XRD Analysis

The structural integrity and homogeneity in the phase of the CoFe_2O_4 synthesized using the sol-gel auto-combustion method were systematically verified through a comprehensive X-ray diffraction (XRD) analysis, as illustrated in Figure 5. The discernible diffraction peaks observed in the XRD pattern were meticulously cross-referenced with the established JCPDS (#22 1086) reference, thereby establishing their conformance with the face-centered cubic (FCC) crystalline configuration. The salient diffraction reflections correspondingly attributed to the (220), (311), (222), (400), (422), (511), and (440) crystallographic planes intrinsic to the CoFe_2O_4 spinel phase were unambiguously identified [32]. This coherent diffraction profile unequivocally confirms the singular presence of the cubic spinel structure, indicative of a pure and uniform phase formation within the synthesized specimens. Notably, the preeminent intensity peak, designated as (311), has been employed with specificity to deduce the characteristic size of the crystallites. The comprehensive X-ray diffraction analysis performed serves as a robust method for corroborating the successful synthesis of CoFe_2O_4 nanoparticles via the sol-gel auto-combustion process. The alignment of the observed diffraction pattern with the established reference further attests to the reliability and accuracy of the synthesized material's crystalline structure determination. Moreover, the distinct identification of diffraction reflections corresponding to specific crystallographic planes underscores the well-defined nature of the crystalline domains, affirming the consistent phase homogeneity throughout the synthesized samples. The characterization of crystallite size through the utilization of the most intense peak, i.e., (311), holds pivotal significance in providing insights into the nanostructured nature of the synthesized CoFe_2O_4 .

This approach enables the quantitative assessment of the dimensionality of the crystalline domains, contributing to a deeper understanding of the material's physical properties and behavior at the nanoscale. Consequently, the XRD analysis conducted not only validates the successful synthesis of CoFe_2O_4 but also furnishes critical structural and dimensional information, laying the foundation for subsequent investigations and applications in various scientific and technological domains.

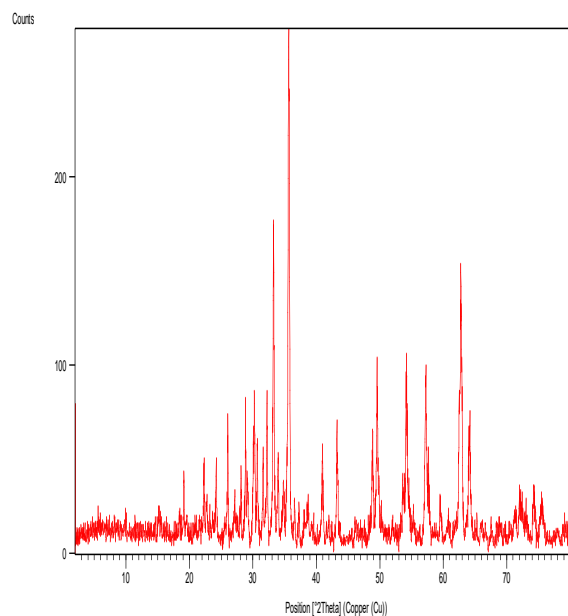


Figure 5. X-ray diffraction (XRD) pattern of the spinel cobalt ferrite oxide nanoparticles synthesized via sol-gel auto combustion method.

An insightful correlation between temperature variation and nanoparticle size augmentation is elucidated through the XRD analysis. This is exemplified by the observed tendency for particle size enlargement with increasing temperature, accompanied by concurrent mitigation of lattice imperfections and strains. This interplay is found to foster the coalescence of crystallites, thus leading to an elevation in the average nanoparticle dimensions [32]. Notably, at elevated temperatures, such as 600°C or beyond, the magnetization trends upwards in tandem with the temperature rise.

3.4. Seawater samples Results

Seawater samples were obtained from the coastal region of Libya, specifically Tripoli. The essential parameters characterizing the seawater were meticulously determined within the controlled environment of the Faculty of Science at the University

of Sebha. The quantified results of these parameters are comprehensively presented in Table 5.

Tab.5 Properties of seawater samples.

Type	Conductivity(mc/cm)	pH	TDS	Salinity (ppm)
Sea water	39.4	7.38	19311.89	21.615

3.5. Effect of Nano (CoFe₂O₄) with *Commiphora Myrrha* on crude oil removal %

Illustrated in Figure 6 is a conspicuous correlation delineating the interrelation between the degree of reduction in crude oil removal from seawater and the deliberate manipulation of particle size as applied to *Commiphora Myrrha*. The empirical findings presented in this visual representation unambiguously delineate a progressively enhanced effectiveness in the process of oil removal as a direct consequence of diminishing particle dimensions within the *Commiphora Myrrha* context. Notably, the Nano iteration of *Commiphora Myrrha* emerges as an exemplar of heightened efficiency in the realm of oil removal, particularly when considered within the framework of a specific composition ratio, denoted as 20:80. Within this compositional configuration, a notable spectrum of oil removal efficacy is conspicuously manifested, spanning from 22.63% to a substantial 30.70%. These delineations robustly underscore the exceptional proficiency of the Nano variant, firmly substantiating its preeminence in the crucial task of oil removal from seawater within the specified parameters of the investigation.

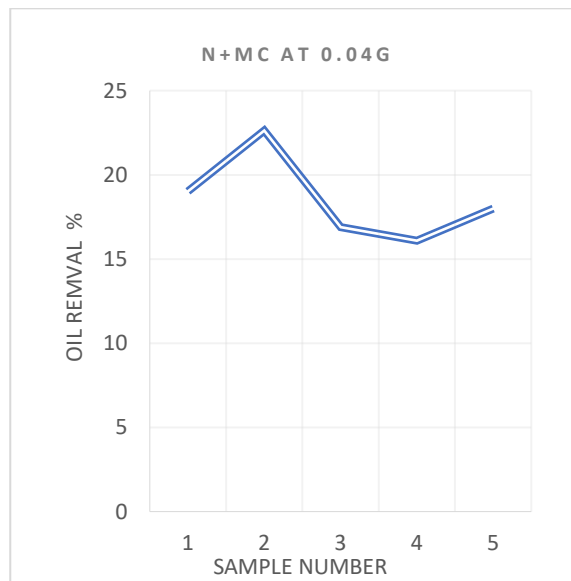


Figure 6. Removal efficiency percentage of Nano (CoFe₂O₄) with CM at 0.04.

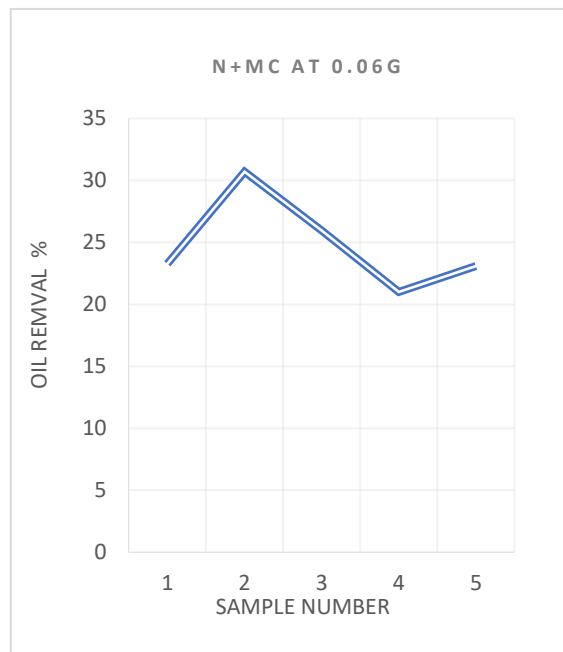


Figure 7. Removal efficiency percentage of Nano (CoFe₂O₄) with CM at 0.06.

3.6. Effect of Nano (CoFe₂O₄) with Coal fly ash on crude oil removal %

Illustrated Depicted in Figure 8 is a conspicuous and discernible pattern, wherein the proportional decrease in particle size attributed to coal fly ash correlates with an augmented reduction percentage concerning the elimination of crude oil from seawater. The empirical findings presented in this visual representation definitively delineate a progressive elevation in oil removal efficacy consequent to the utilization of nano coal fly ash. Remarkably, this heightened performance is most salient within the context of the 30:70 compositional ratio, where the recorded oil removal percentages span a range from 47.79% to a substantial 69.70%. The conspicuous augmentation in adsorption capacity observed when employing coal fly ash and its cognate counterpart, *Commiphora Myrrha*, can be attributed to the significant amplification in the ratio of exposed surface area to volume. This geometric alteration enables a more extensive interface for oil adsorption, thereby fostering an increased capacity for oil binding and coalescence on the material's surface. Consequently, this augmented adsorption capacity translates into heightened oil agglomeration and, in turn, superior efficiency in the removal of oil contaminants from the aqueous medium. The findings underscore the potential utility of tailored particle size manipulation in optimizing the performance of materials intended for oil removal applications. Such insights, rooted in materials

science and interfacial phenomena, not only advance the fundamental understanding of adsorption processes but also present practical implications for enhancing the efficacy of remediation strategies in the realm of marine oil pollution [33].

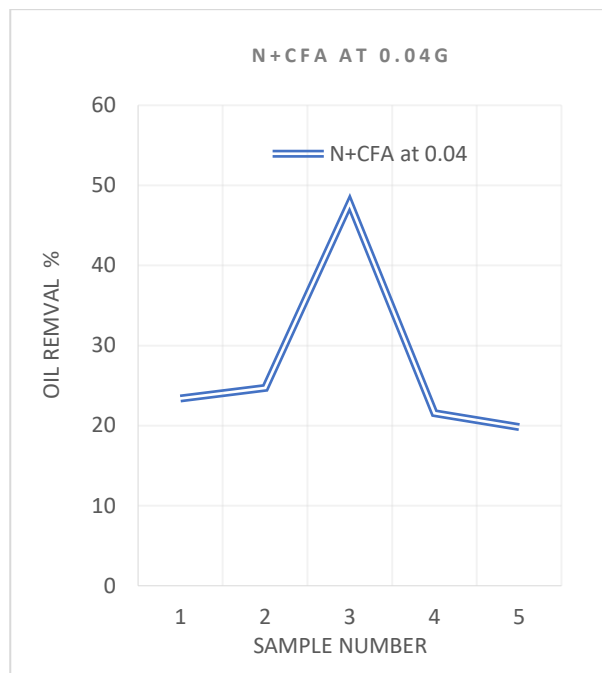


Figure 8. Removal efficiency percentage of Nano (CoFe₂O₄) with CFA at 0.04g.

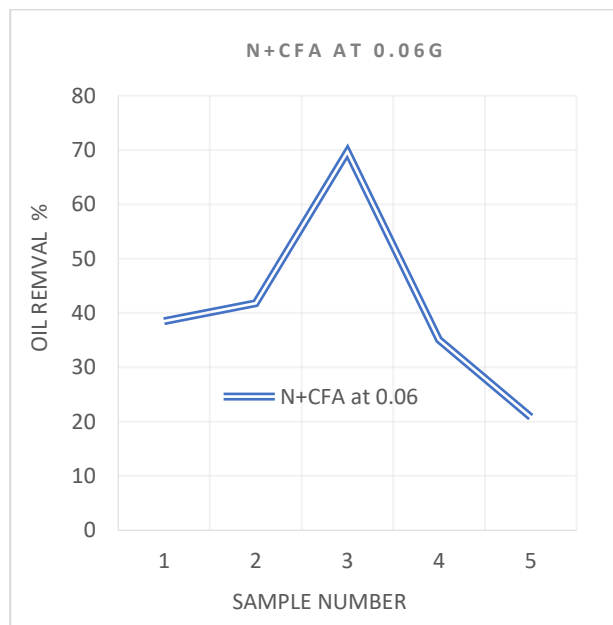


Figure 9. Removal efficiency percentage of Nano (CoFe₂O₄) with CFA at 0.06g.

4. Conclusion

The obtained results yield pertinent conclusions that merit elucidation. Firstly, it has been discerned that the utilization of Nanoparticles CoFe₂O₄ exhibits a notable efficacy in the removal of crude oil from seawater. Moreover, the strategic augmentation of Coal Fly Ash in conjunction with Nanoparticles CoFe₂O₄ has been identified as a viable approach to enhance absorbent capacity while concurrently mitigating cost implications. In a parallel vein, the integration of the natural substrate Commiphora Myrrha with Nanoparticles CoFe₂O₄ has yielded compelling outcomes in the domain of oil removal. Notably, this amalgamation has achieved substantial oil removal efficiency, quantified at an impressive 30.70%, particularly under the conditions of an 80:20 ratio at a concentration of 0.06g. Equally remarkable, the introduction of Coal Fly Ash as an absorbent agent has exhibited an even higher oil removal efficiency, registering an impressive 69.7%. This enhancement was most pronounced when adopting a 70:30 ratio at the same concentration of 0.06g. It is evident from these findings that the interplay between diverse materials and their ratios, along with concentrations, exerts a discernible influence on the overall efficacy of oil removal processes. Consequently, these findings not only contribute to advancing our understanding of effective oil spill mitigation strategies but also offer practical insights for optimizing the balance between performance and economic feasibility. Further research and explorations in this realm are encouraged to refine and expand upon these promising findings, thus fostering a more comprehensive framework for addressing oil contamination challenges in aquatic environments.

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