Efficient Oil Recovery as Conventional Energy Using Smart Graphitic Nanocomposite

Sanction Order No. & Date: SAN No. BT/HRD/NBA/39/15/2018-19 Dated.18.03.2019

Progress report of 2019-2023

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Scientific and Technical Progress Report (STPR)

(R & D Projects)

Section A: Project Details

1. **Title of the Project : Efficient Oil Recovery As Conventional Energy Using Smart Graphitic Nanocomposite**

2. **Name & Address of the Awardee/Fellow:** Prof. P. Deb,
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3. **Date of Sanction**: 17-03-2019.

4. **Date of Completion:** 31-01-2023.

5. **Total cost :** Rs. 1503494.00/- (including interest earned)

6. **Budget Released:** Rs. 1495784.00/-

7. **Approved Objectives:**

   - To prepare composite of two dimensional (2D) graphitic carbon nitride (C_3N_4)/graphene sheet and 1D chain like Iron nickel ($FeNi_3$) structure.

   - To make the 2D g-C_3N_4@$FeNi_3$ nanocomposite oleophilic and hydrophobic in nature.

   - To check the efficiency of crude oil adsorption using this magnetic nanocomposite and subsequent extraction of oil.

   - To check the reusability of the used nanocomposite in oil extraction.

   - To check the purity of the water after oil removal, for its natural use.

DBT has granted sanctions for my project proposal entitled "Efficient Oil Recovery As Conventional Energy Using Smart Graphitic Nanocomposite" vide letter no. 102/IFD/SAN/5141/2018-19 dated 17.03.2019 through sanction (Sanction No. BT/HRD/NBA/39/15/2018-19 dated 18.03.2019) for the implementation of the project.

Contents **Page number**

8. Progress made under the project vis-à-vis objectives (in details):

(i) Development of library of 2D, 1D, 1D/2D hybrid nanosystems for efficient oil removal application.
(ii) Twelve papers published in international peer reviewed journals.
(iii) One paper published in national peer reviewed journal.
(iv) Four patent applications filed.
(v) Three conference presentations.
(v) Three PhD completed and seven PhD ongoing in the related research area.
(vi) Seven MSc students completed their major research projects.

A. Results and Discussion

A.1. Development of surface modified 2D g-C_3N_4@$FeNi_3$ nanocomposite

Abstract: Efficient oil absorption and recovery is of universal importance for future energy demand and environmental protection. Adsorbents based on 2D flatland with engineered surfaces can overcome the limitations of conventional methods for selective oil absorption. Here, we report magnetic hydrophobic/oleophilic graphitic nanosheets that exhibit excellent oil sorption performance and ready removal of adsorbed oil using an external magnet. Porous flatland sheet combined with magnetic $FeNi_3$ and further surface engineered with fatty acid have built the system as ideal adsorbent.

Surface modification: For making the composite oleophilic in nature, the sheet surface was modified with fatty acid named as stearic acid. Fatty acid was used for maintaining the wettability, hydrophobicity and oleophilicity of the system. After surface modification, the hydrophobic and oleophilic nanocomposite exhibits a selective absorbance for oil recovery. When brought into contact with a layer of crude oil in oil-water mixture, the nanocomposite absorbs the oil instantaneously repelling the water. Surface modification was analyzed with the help of contact angle where the angle measurements ensured the wettability transition of the nanocomposite. The increase in contact angle up to 140^0 implied the hydrophobic and oleophilic nature of the prepared nanocomposite material.

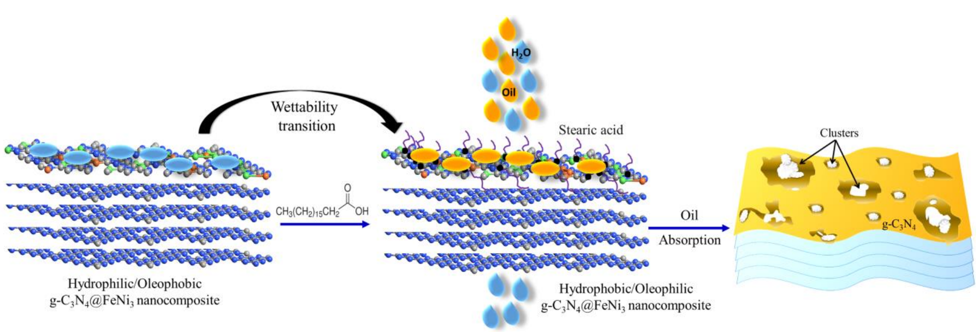

Figure.1 Schematic representation of prepared hydrophobic graphitic magnetic nanocomposite for efficient oil-water separation

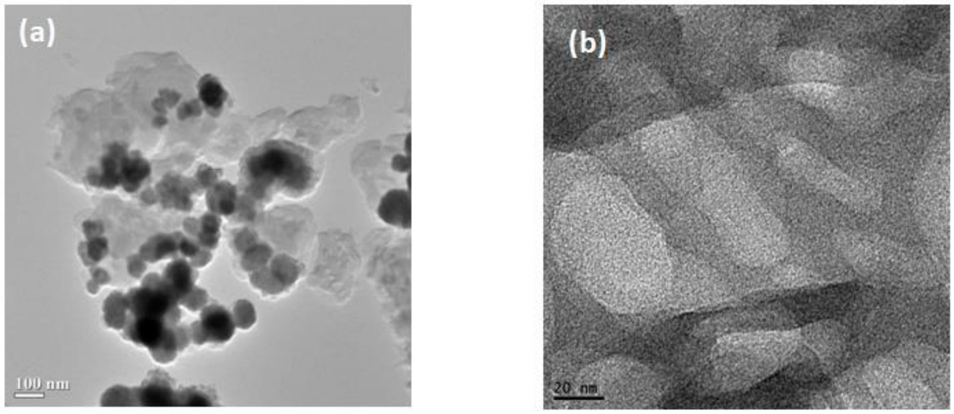

Figure 2. Presents the transmission electron microscopy (TEM) image of (a) composite i.e. g-C_3N_4@$FeNi_3$ (b) pristine graphitic carbon nitride

A.2 Characterizations and Efficiency of crude oil adsorption using g-C_3N_4@$FeNi_3$ nanocomposite

Oil removal efficiency calculation: In order to enable easy and quick removal of the crude oil, magnetic separation was done to separate the viscous oil. The removal efficiency was calculated using the formula

$$n = (m_2 - m_1)/c_0$$

Where m_1 is the nanoparticles before extraction and m_2 is the amount of nanoparticles after oil extraction. C_o is the amount of crude oil taken in each case. The outcome efficiency of crude oil extraction was found to be 92% with the prepared magnetic nanocomposite.

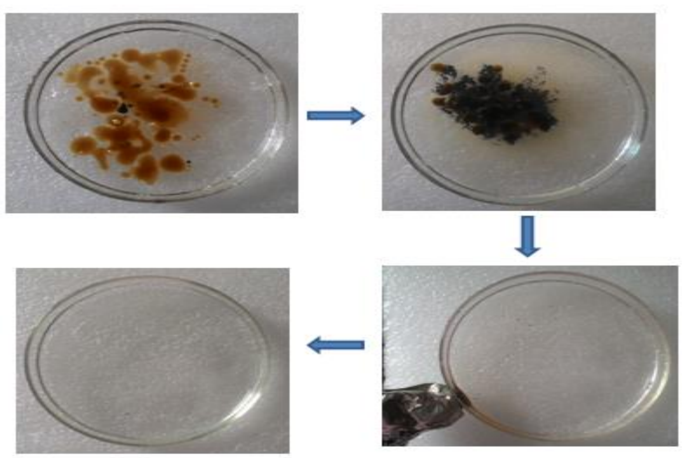

Figure 3. Presents the removal of oil from the water using g-C_3N_4@$FeNi_3$ with the help of magnet

A.3 Reusability

Oil recovery and reusability: The graphitic magnetic nanocomposite can be further recycled and reused for oil adsorption and separation in an easy and quick manner. The system can be further reused easily by washing and drying the composite. Apart from reusability of the nanocomposite, further removed oil can be recovered successfully.

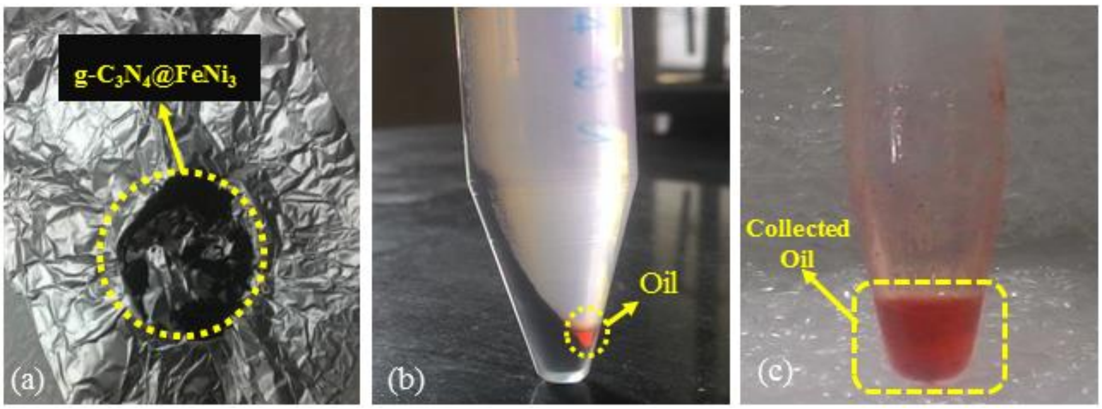

Figure 4. Recovery of oil after separation.

Conclusion: We develop a novel and smart surface engineered sorbent material to realize magnetic separation of viscous oil from oil-water mixtures. The stearic acid based surface functionalized nanocomposite exhibits not only wettability transition from hydrophilicity to hydrophobicity, but also selective oleophilicity in removal of oil from water body. 2D graphitic flatland with precise surface area and high proportion of mesopore achieves near-absolute adsorption efficiency (i.e. 100%) of crude oil. As a result, the sheet thickness enhanced up to 9 times than the pristine one. The nanocomposite efficiently recovers crude oil from water surface under an external magnet with a quick response of < 1sec. Apart from the crude oil, the composite system selectively absorbs a wide range of oils. Thus, the prepared g-C_3N_4@$FeNi_3$ nanocomposite acts as an ideal absorbent material for efficient oil recovery and hence provides feasible solution towards the upcoming oil consumption.

A.4 Development of 2D Fe_3S_4 and $ZnCo_2O_4$ Nano sheet and to certify its efficiency in oil recovery

Abstract: Oil spillage cases are rapidly increasing in the present scenario. As a result, it is vital to choose an appropriate sorption material for oil removal from water bodies. Currently, it is a global challenge to develop one sorption material with optimum water repelling property as well as oil absorption capacity for oil-removal purpose. Low capture performance and minimum specific surface area with less micro-pore proportion of the available absorbent materials are key drawbacks that hamper their practical applications in crude oil removal. To overcome the global challenge, two dimensional (2D) materials with specific surface area are considered as novel and suitable candidate towards absorption processes. In this regard, we have developed two different systems of 2D Fe_3S_4 and $ZnCo_2O_4$ Nanosheets stacked and separated by weak van der Waals (vdW) forces. This maiden study has reported magnetic hydrophobic/oleophilic graphitic sheets exhibiting excellent oil sorption performance and readily removal of absorbed oil using magnetic field. The merits of this behavior of the individual systems are beneficial to be used as ideal sorbent for oil removal.

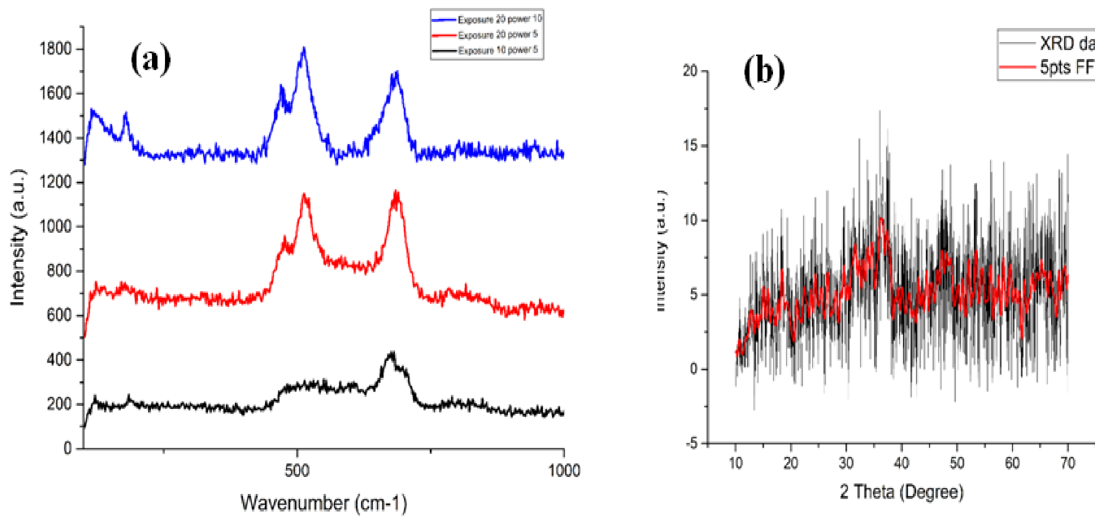

Figure 5. (a) Raman spectroscopic and (b) XRD plot of prepared $ZnCo_2O_4$ nanosheets

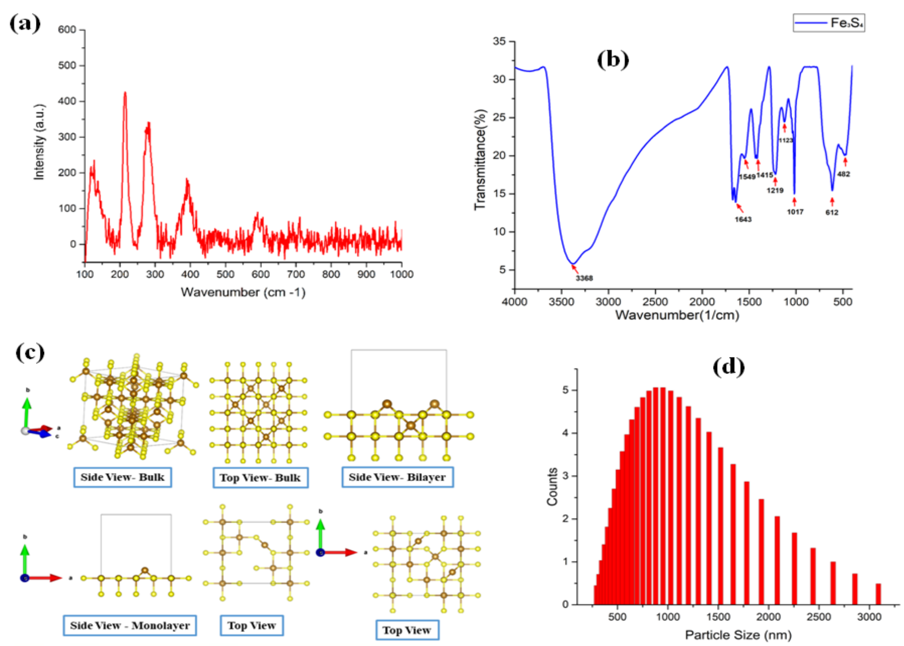

Figure 6. (a) Raman spectroscopic (b) FTIR plot, (c) Surface Atomic Configuration and (d) Dynamic Light Scattering (DLS), of prepared Fe_3S_4 nanosheets

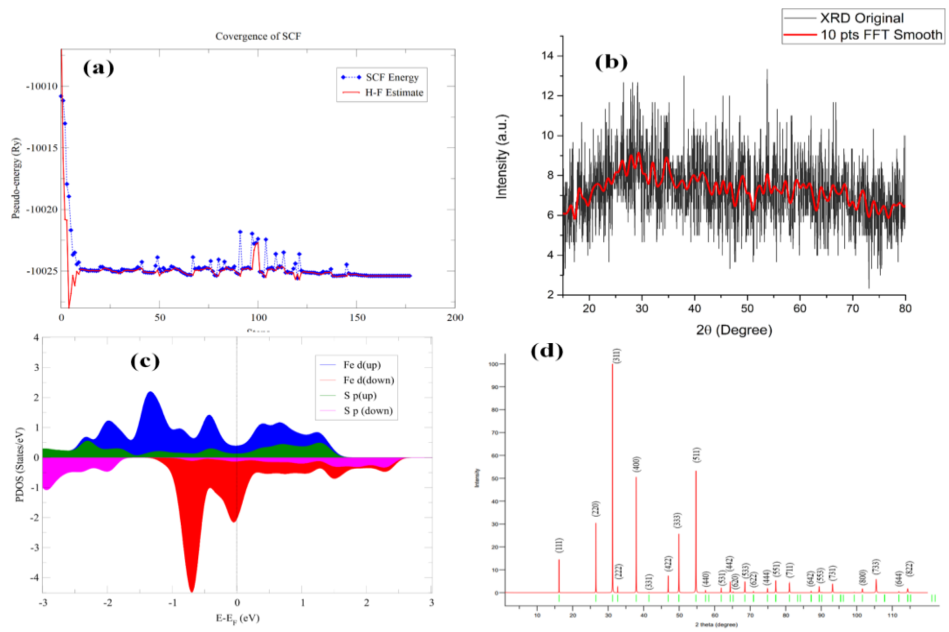

Figure 7. (a) Density of State calculation (b) XRD, (c) Partial DOS spin polarization and (d) Simulated XRD pattern of Fe_3S_4 nanosheets

Conclusions: The study has addressed two different systems as smart sorbent material for efficient oil recovery in presence of external magnet via implementing experimental studies supported by density functional theory calculation. This study reveals the novelty to understand the role of surface area with pore distribution in two dimensional nanosheets like composite materials and its effect towards oil absorption capacity and response time. Taken together, these results hold the promise that the individual nanosystems act as promising absorbent material for efficient oil recovery providing feasible solution towards the upcoming oil consumption.

A.5 Development of 2D CuSe nanoflakes based sponge for oil recovery:

Abstract: Development of absorbent material for oil and organic solvents is critical for removing contaminants from the water surface. Advancement of an oil absorber with a significant contribution for structural parameters of porous configuration of materials is highly coveted in order to ensure crude oil supply for future generations. In this study, we demonstrate structural parameters of the pores of surface modified two-dimensional (2D) CuSe nanoflakes engineered polyurethane (PU) sponge, with combination of synergistic low surface energy and surface roughness, playing an important role in the efficient removal of oil from water. Due to large surface of porous sponge and two dimensional nanoflakes along with their interface, the system showed an efficient crude oil uptake capacity of more than 37 times of its original mass. Furthermore, the developed system can be recycled and reused 50 times while maintaining high crude oil absorption efficiency, and even after 50 cycles, the system has retained good recycling absorption

capacity, indicating the brilliance of the system. In addition, the system has promising implications as a favorable absorbent for crude oil–water separation due to its quick absorption (1.5 s) and high separation efficiency (96%). The selective absorption efficiency, quick oil-absorption rate, large amount of oil separation with high efficiency under one platform, has been implemented in a device for technological application in large scale.

Surface Modification: For developing the 2D CuSe nanoflakes based sponge oleophilic in nature, the coated sponge was surface functionalized with fatty acid named as stearic acid. Stearic acid was utilized for sustaining the wettability, hydrophobicity and oleophilicity of the system. After surface functionalization, the CuSe coated sponge exhibits hydrophobicity and oleophilicity for selective absorbance of oil. When CuSe based sponge is brought into contact with a layer of crude oil in oil-water mixture, the coated sponge immediately absorbs the oil repelling the water. Surface functionalization was obtained with the help of contact angle where the angle measurements ensured the wettability transition of the nanosponge. The increase in contact angle up to 131.70 implied the hydrophobic and oleophilic nature of the prepared nanosponge.

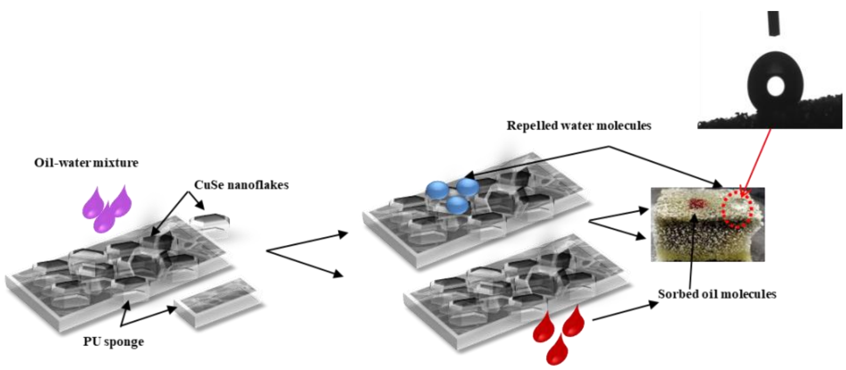

Figure 8. Schematic depiction of the process of oil-water separation using surface modified CuSe coated sponge

Results:

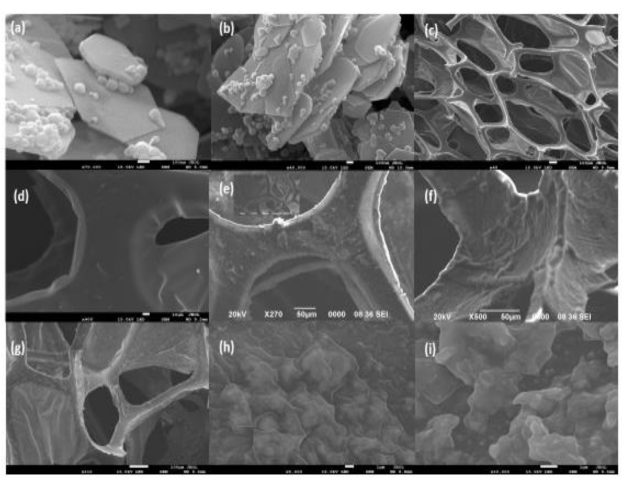

Figure 9. FESEM images of (a)-(b)CuSe nanoflakes at different magnifications, (c)-(d) pristine PU sponge, (e)-(f) CuSe coated sponge, (g)-(i) surface modified CuSe coated sponge.

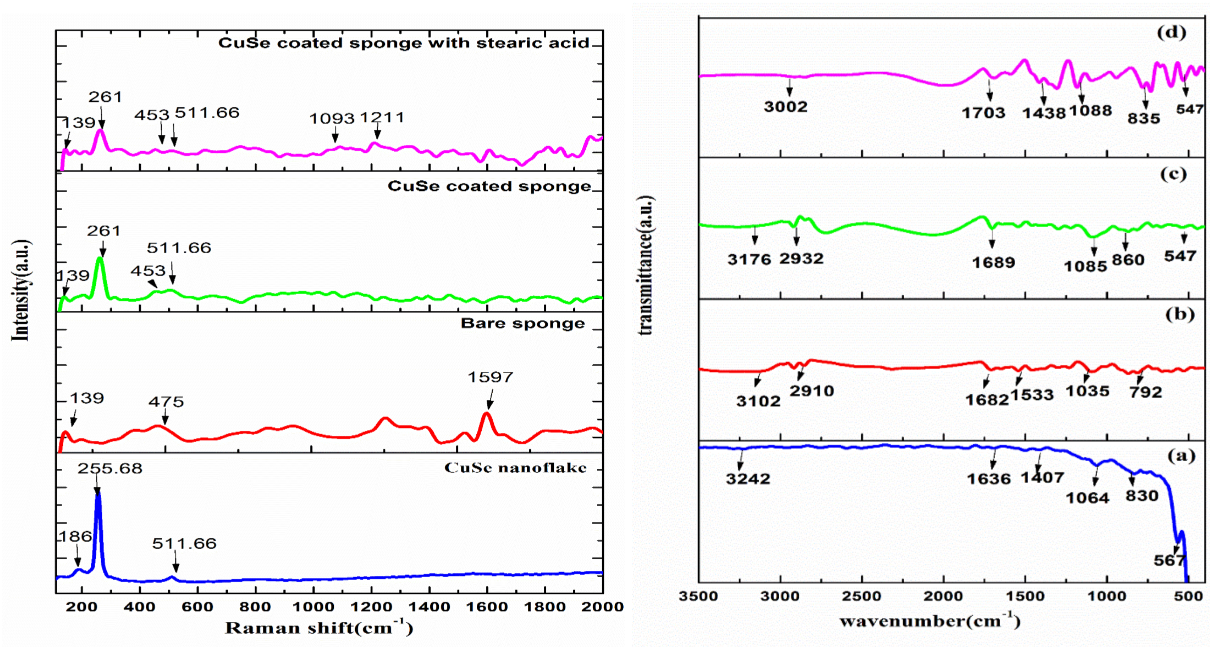

Figure 10 (Left panel). Raman spectra of (a) CuSe nanoflakes (b) bare sponge (c) CuSe coated sponge (d) CuSe coated sponge with stearic acid. (Right Panel) FTIR spectra of (a) CuSe nanoflakes (b) bare sponge (c) CuSe coated sponge (d) CuSe coated sponge with stearic acid.

A.6 Characterizations and Efficiency of crude oil adsorption using 2D CuSe nanoflakes based sponge

Evaluation of absorption efficiency: In order to calculate the quick removal of crude oil, the CuSe coated sponge was dipped in oil-water mixture to separate the viscous oil. The following equation has been used to measure absorption efficacy (n) of surface functionalized CuSe coated sponge.

$$n = (m_2 - m_1)/c_0$$

Where m1 represents the weight of coated sponge before oil absorption, m2 represents the weight of coated sponge after complete oil adsorption and c0 represents the weight of the added crude oil. The maximum absorption efficiency with surface modified CuSe-based sponge for 16 % stearic acid was found to be 99.08 %.

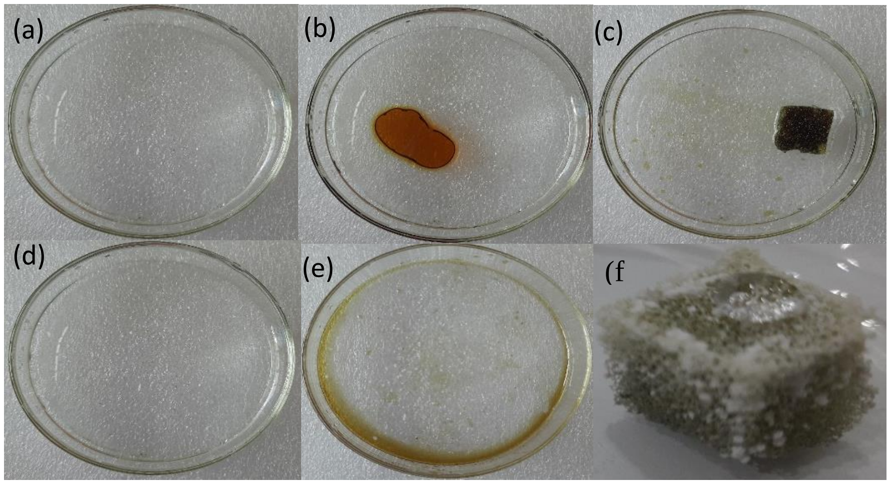

Figure 11. Digital images (a–e) depict the oil-water separation process (f) Hydrophobic property of surface modified CuSe coated sponge.

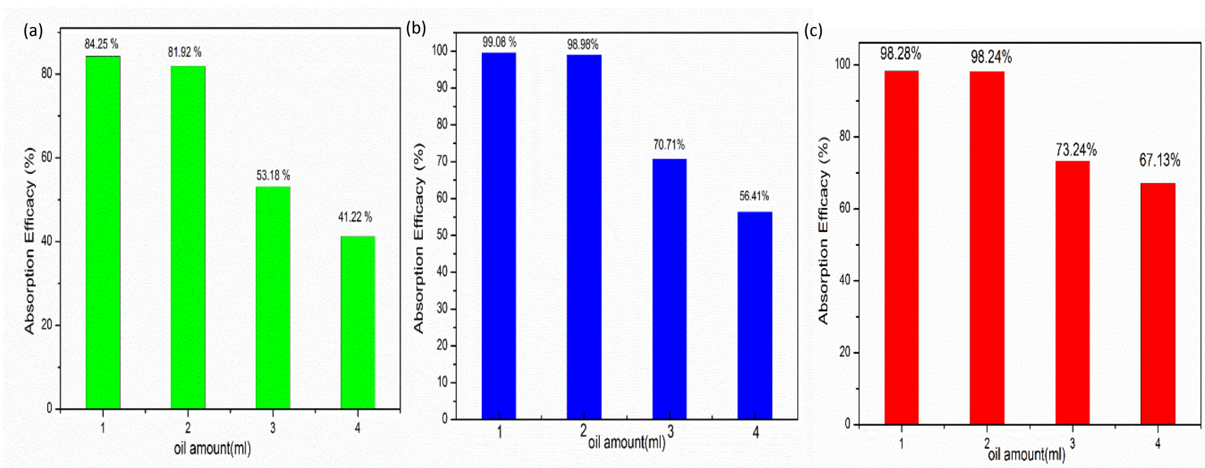

Figure 12. Efficiency of absorption as a function of the volume of oil used with different concentration of stearic acid (a) 8% (b) 16% (c) 32%.

Conclusions:

A surface engineered CuSe coated sponge with excellent oil/water separation properties has been successfully prepared via simple immersion method. The sponge with hydrophobicity and oleophilicity was fabricated using a simple, gentle, and low-cost process, and it has a lot of potential for separating crude oils from water. The sponge's oil absorption process took just a few seconds, and there was no evidence of water in the sponge. Furthermore, it had excellent oil selectivity, high hydrophobicity (water contact angle=131.70), high absorption capacity (99.08%) and good recyclability. The sponge produced in this study has the potential to be a useful material for removing oils and organic impurities from water on a large scale.

A.7 Technologies developed: ***Device architecture for removal of oil spillage*****:**

Abstract: The oil spill removal device has been developed to remove crude oil from oil spill site in hard ground. It will use the developed 2D CuSe coated sponge to collect oil from ground and stores in a container, which can later be purified and will be useful for different purposes. The model of the device is a basic representation of its working. It has a wooden base, an axle attached to the base having a movable arm. The nano sponges are attached to the movable arm with adhesives. There are two D.C motors attached, one with the wooden base for angular rotation of the axle and the other one is with the axle for the up and down movement of the arm. Along with the motors, spur gears are connected for the smooth rotation. To move the whole model on the ground, four wheels are connected on the four corners of the wooden base. Two D.C motors are connected in two of the wheels for its movement in different directions. After that a container with net attached to it is fixed on the base to store the oil. To supply power to the motors, a 12 V battery will be required. The rotation of the motors will be controlled by motor driver modules and ESP32 microcontroller board. After providing the coding information to ESP32 board it will eventually be controlled by an android application from mobile phone via wi-fi connectivity.

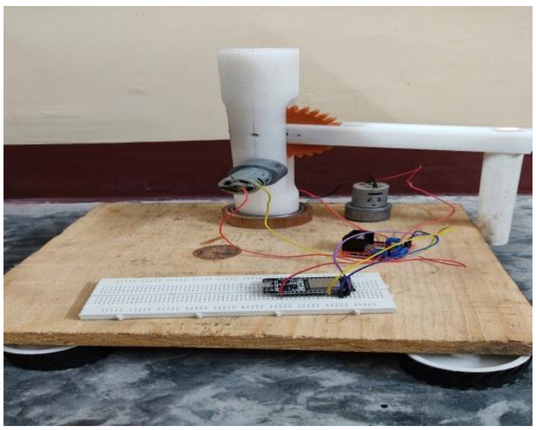

Figure 13. Device for removal of crude oil from the ground.

A.8 Technologies developed: ***Development of a conveyor belt for cleaning the oil spill*****:**

Abstract: Exxon Valdez, Alaska (1989), Chennai (2017), Mauritius (2020), Deep water Horizon (2010), all these places located in different latitude and longitude of the globe have one thing shared in common. These are the few places to be named in a long list of places suffered from environmental disaster caused by oil spill. It has an adverse impact on the flora and fauna of the region, which is clearly visible in marine fish species. However, traditional techniques such as bioremediation, chemical treatment by dispersants etc have been used to clean spilled oil but it has its limitation in higher rate of cost with lower efficacy. To overcome this limitation, a prototype has been designed on the principle of the conveyor belt. Different components are assembled together to complete the design. It consists of two rectangular frame, four Cylindrical rotor, two spur gears, belt, 12 V DC motor, 5 V relay switch, Robodo L298 Motor Driver module, 9 V batteries, sponges, metal rods, connecting wire, plastic bottles, containers. The cylindrical rotors which are the backbone of the system are placed between the rectangular frame, where one of the rotor is connected to the motor through a pair of gears, the belt connected through the rotors and sponge is placed above it which is passed between the two metal rods whose function is to squeeze the sponge. The motor is controlled by a Motor driver module with the help of relay switch through a mobile application. The entire system is designed to collect oil from water and for this purpose plastic bottles are being used; the bottles are connected to the rectangular frame which in turn keeps the system afloat in the water.

Figure 14. A device prototype for cleaning oil spill.

A.9 Development of High connectivity hierarchical porous network of polyurethane engineered by nanoflakes for proficient oil recovery

Abstract: Development of absorbent material for oil and organic solvents is critical for removing contaminants from the water surface. Advancement of an oil absorber with a significant contribution for structural parameters of porous configuration of materials is highly coveted in order to ensure crude oil supply for future generations. In this study, we demonstrate structural parameters of the pores of surface modified two-dimensional (2D) CuSe nanoflakes engineered polyurethane (PU) sponge, with combination of synergistic low surface energy and sur face roughness, playing an important role in the efficient removal of oil from water. Due to large surface of porous sponge and two dimensional nanoflakes along with their interface, the system showed an efficient crude oil uptake capacity of more than 37 times of its original mass. Furthermore, the developed system can be recycled and reused 50 times while maintaining high crude oil absorption efficiency, and even after 50 cycles, the system has retained good recycling absorption capacity, indicating the brilliance of the system. In addition, the system has promising implications as a favourable absorbent for crude oil–water separation due to its quick absorption (1.5 s) and high separation efficiency (96%). The selective absorption efficiency, quick oil-absorption rate, large amount of oil separation with high efficiency under one platform, has been implemented in a device for technological application in large scale.

A.10 Development of stearic acid functionalized CuSe coated PU sponge (SACSPUS) for proficient oil recovery: The procured sponges were ultrasonically washed in ethanol for a period of 1 hr to remove feasible impurities and then dried at 600 for 3 hr. Then, the washed pieces of sponges were dipped into a solution containing 40 mg of CuSe nanoflakes and 10 ml ethanol, which was followed by ultrasonication for 1 hr and then kept in oven for 3hrs. In the synthesis method, the yellow color sponge changed into black color after treatment with CuSe solution. The CuSe coated sponges were immersed in fatty acid solution (2-8 wt. %) and kept for 16 hrs at room temperature (RT). Finally, obtained sponges were dried at 600C for a period of 8 hr. Then, SACSPUS could efficiently repel water and absorb oil from oil-water solution. After modification with fatty acid, the black color CSPUS became silverish shine black color. Figure 15 showed the schematic representation of the development of SACSPUS for continuous oil absorption and recovery.

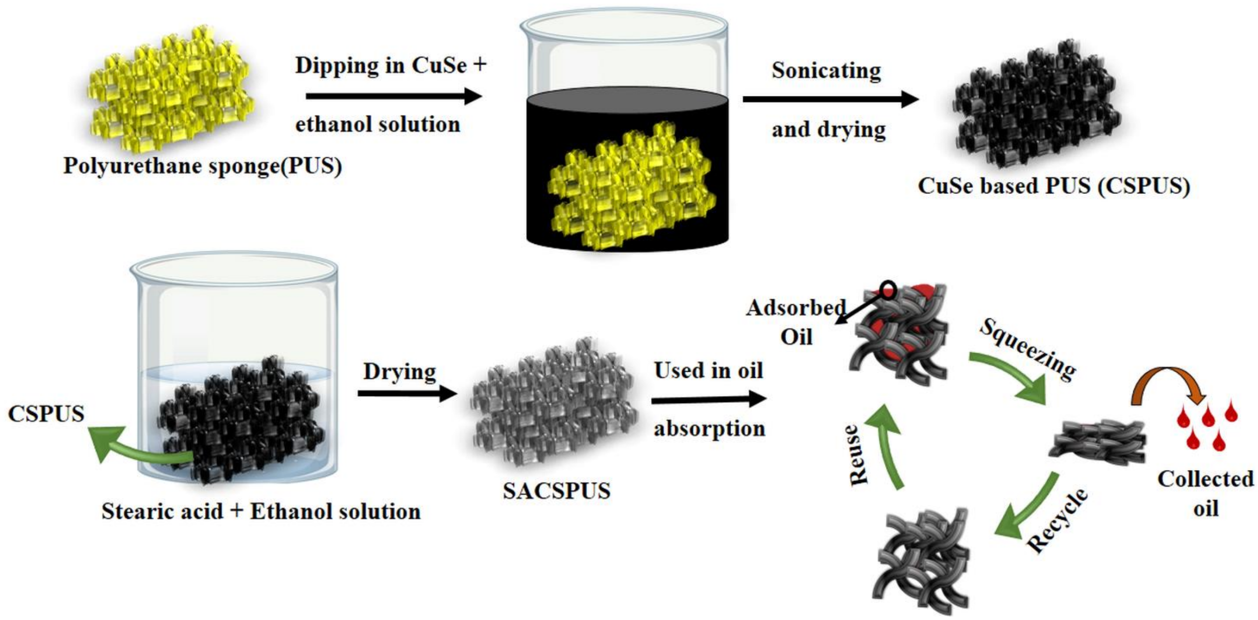

Figure 15. Schematic depiction of the PU sponge modifying process for oil-water separation.

Results

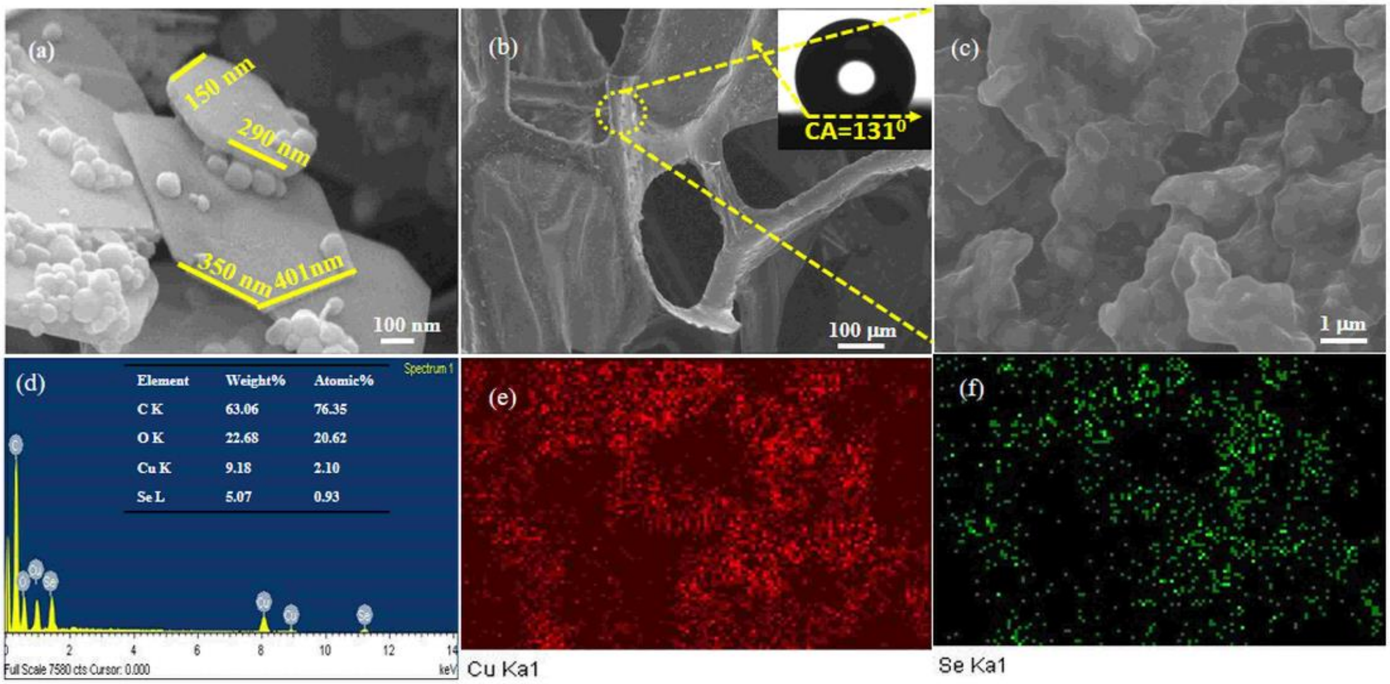

Figure 16. SACSPUS morphological study. FESEM micrographs of (a) CuSe nanoflakes, (b) SACSPUS; inset: Contact angle of SACSPUS, (c) Zoomed version of highlighted area of SACSPUS, (d) EDX spectrum of CSPUS, (e) elemental mapping images depicting the distribution of copper (Cu), (f) selenium (Se).

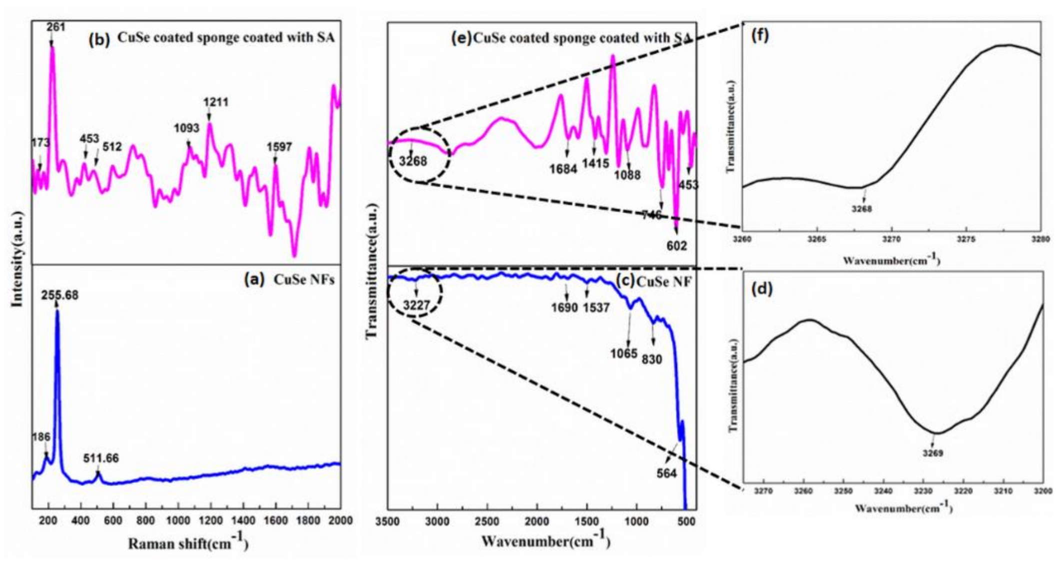

Figure 17. Surface chemistry. Raman images of (a) CuSe and (b) SACSPUS. FTIR images of (c) CuSe and (e) SACSPUS. Zoomed versions of the N-H characteristic peaks in (d) CuSe and (f) SACSPUS.

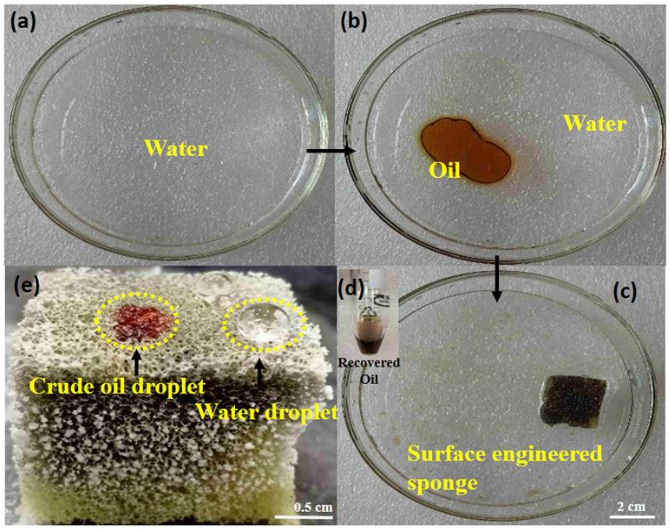

Figure 18. Hydrophobicity and oleophilicity.(a–c) oil-water separation process; (d) inset: Oil removal by squeezing the SACSPUS. (e) Engineered SACSPUS exhibiting oil absorption and water repletion capacity.

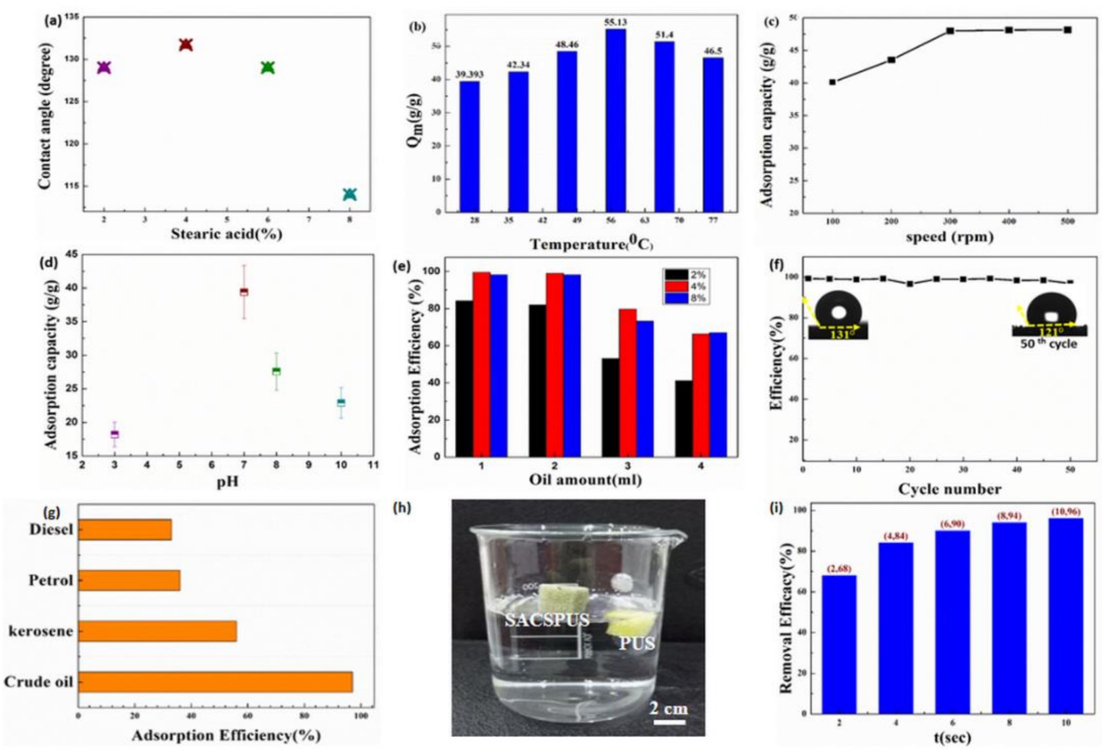

Figure 19. Crude oil absorption validation. (a) Contact angle variation of SACSPUS with different SA concentrations (2, 4, 6 8%). Absorption efficiency as a function of (b) temperature, (c) wave, (d) pH, (e) volume of oil used with different SA concentrations (2, 4, 6 8%), (f) recyclability test of SACSPUS, (g) Absorption capacity of SACSPUS with different types of oil. (h) Hydrophobicity and hydrophilicity of SACSPUS and pristine sponge respectively. (i) Separation efficiency as a function of time.

A.11 Mechanism associated within the system due to interaction between the pore wall and the oil absorbed:

Pore-filling and hydrogen bonding interactions are significant physical interactions that occur at the outer surface of the absorbents. It is observed that air molecules clogged the pores of SACSPUS as shown in Figure 20. During the absorption process, two main phenomena took place. Firstly, oil filled the pores on the surface of SACSPUS by removing air, owing to reduced SACSPUS's surface energy. Secondly, through capillary action, oil diffused inside the pores of the system, hence, converting the air-filled SACSPUS to an oil-filled SACSPUS (as shown in Figure 20a). In this regard, pore sizes and connectivity (ODHC, ODMC, ODLC) had an impact on capillary pressure and thus played an important role in the absorption process. In PUS, the absorption capability was low due to presence of ODHC, ODMC and ODLC (Fig. 6a-c). When PUS is coated with CuSe NFs, the consequences were as follows: (a) converting ODMC and ODLC present in pristine sponge into ODHC (Figure 20b) (b) resulting formation of a rough surface on CSPUS due to existence of few-layer CuSe NFs on the porous network of sponge (Figure 20c, d), (c) increasing contact area due to interface of PUS and 2D flakes. It was observed that, CSPUS with ODHC pores (pore sizes 250-1100μm) could hold oil within their cavities owing to high pressure (P) referred to the appropriate size of the cavities (Figure 21). Moreover, the system had high absorption capability due to strong interaction of CuSe NFs with pore wall of sponge and enhanced capillary pressure (Figure 20d). In this regard, CuSe coating modified the surface chemistry of pores by enhancing oleophilicity, resulting in enhanced capillary pressure in medium and low pore connectivity of the sponge. Moreover, the system was functionalized with SA improved oil selectivity over water (Figure 21d). An improved pore connectivity in hierarchical SACSPUS structure with a larger contact area enabled more oil particle absorption inside the cavities of the SACSPUS system. From Figure 21e, it was observed that absorption of oil led towards formation of smooth surface of the system, indicating that the cavities were filled up by oil particles, i.e. the rough surface of SACSPUS was transformed into smooth surface after oil absorption. It was observed that, after reaching saturation, the smooth surface of SACSPUS could no longer absorb oil. Therefore, SACSPUS was washed with ethanol to activate the system's binding sites, which retains their oil absorption capacity. In order to use the developed SACSPUS system in a pilot scale, a remote controlled oil removal prototype with oil absorbents made of SACSPUS system was developed. One notable advantage of the prototype was the use of rotating wheels, which allowed the device to rotate 360^0, adding significant advantage over devices. The prototype did not require any manual labor as, it was equipped with oil detecting sensors and switches on the arm that detect and collect oil spills automatically. By installing routers in different components of the device, its operation cycles can be increased in oil-spilled areas. In practical application, the developed prototype could complete the oil removal operation within 1 minute 26 seconds to 2 minutes at most. Furthermore, the prototype can complete 5-6 operation cycles in 10 minutes with high efficiency. Hence, the device is quite effective in absorbing oil in short period of time.

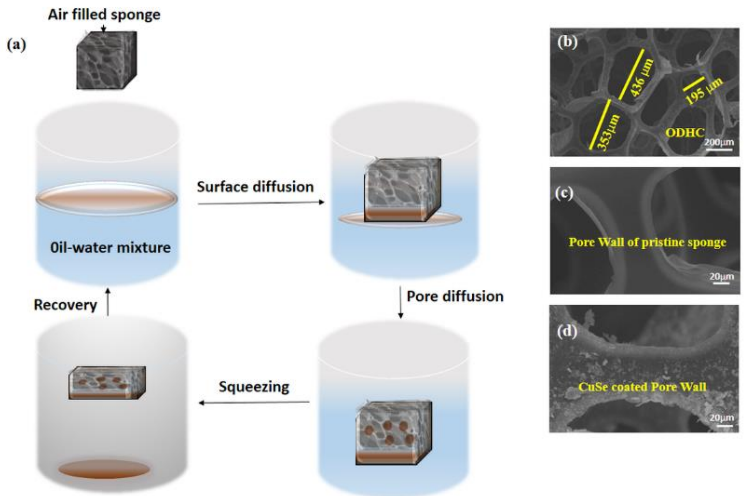

Figure 20. Absorption mechanism associated with SACSPUS. (a) Surface and pore-filling process of SACSPUS system. (b) SEM image of SACSPUS showing ODHC structure with pore size. (c) SEM image of PUs indicating smooth surface of pore wall. (d) SEM image of CSPUS indicating roughness of pore wall.

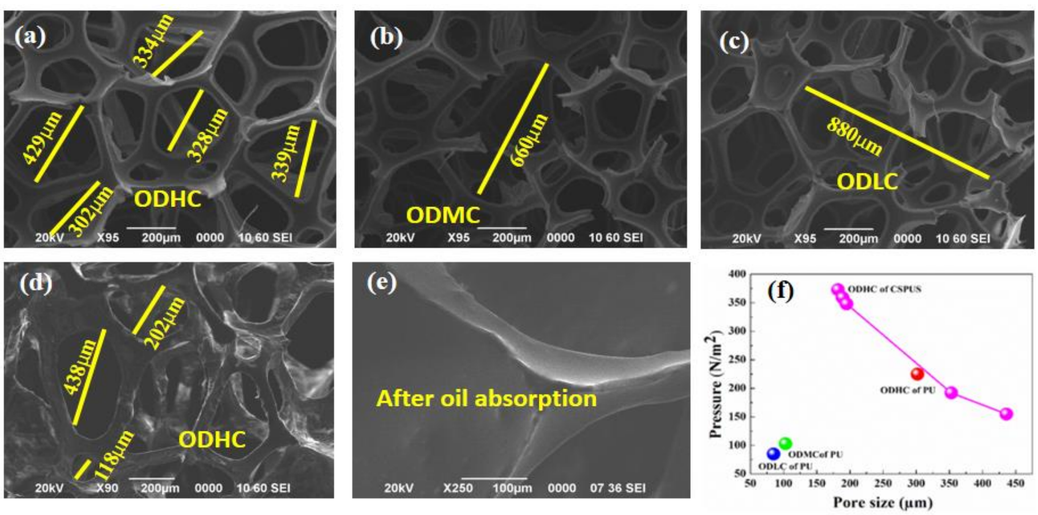

Figure 21. Morphological study to understand pore wall interaction. (a) Degree of connectivity ODHC of PUS. (b) Degree of connectivity ODMC of PUS. (c) Degree of connectivity ODLC of PUS. (d) Degree of connectivity ODHC of SACSPUS. (e) Pore wall structure of SACSPUS after oil absorption. (f) Capillary pressure vs pore size of SACSPUS and PUS.

Conclusions:

Oil spillages cause serious threat and create long-term harm both to human health and ecosystem. Removal of crude oil from oil-water mixture are the most challenging environmental issues that made enormous strides to explore effective cleaning methods. The developed hydrophobic SACSPUS absorbent exhibited high absorption capacity (99.58%) with quick absorption due to the presence of better internal connectivity (ODHC) and appropriate pore size contributing to the capillary pressure through pore wall of SACSPUS. Presence of CuSe not only increases the surface area of pristine sponge by forming a rough surface, but also creates additional pores on the pore wall of the PUS. The oil-absorbed sponge was recovered and reused 50 times, retaining its high absorption capacity even after that. The SACSPUS system absorbed a wide range of crude oil from the oil-water surface quickly (within 1.5 seconds) and efficiently, as well as exhibiting excellent separation efficiency (96%). Pseudo second order kinetics with Langmuir isotherm was found to govern the absorption reaction. Furthermore, a remote-controlled device with SACSPUS absorbents was designed, which has a likelihood of being used in large-scale oil spill clean-up.

A.12 Remote Controlled Device for Collection of Oil from the Oil spill on land:

Abstract: Oil-spill accidents frequently happen during the oil exploration and transportation processes, resulting in energy loss as well as threats to the environment usually bringing catastrophic effects to the marine ecosystem. Therefore, the clean-up of crude oil spills from the spillage site is the most challenging environmental issue that made enormous strides to explore the effective cleaning methods. Various techniques have been tried over the years to tackle this issue, but the absence of adequate oil removal technology continues to remain. So, in order to find a solution, a remote-controlled oil removal device is designed, with oil absorbents made of nanomaterial-based polyurethane (PU) sponges (Figure 22). The present remote-controlled device that uses nanomaterial-based sponge as absorbents and runs on solar power pursuing. The device has a robotic arm to which the nanomaterial-based sponges are attached, and it absorbs the oil from the spill site while also separating it from the sponge, with the oil collected in a container attached to one side of the substrate. One notable advantage is the use of rotating wheels, which allows the device to rotate 180 degrees, which is a significant advantage over other devices on the market. Moreover, the present device can collect the oil spill using a variety of absorbent materials. It is also ideal for use in land oil spills due to its low cost and light weight. The developed hydrophobic absorbent exhibited high absorption capacity with quick absorption due to the presence of better internal connectivity (ODHC) and appropriate pore size contributing to the capillary pressure through pore wall of absorbent. Presence of 2D materials not only increases the surface area by forming a rough surface, but also creates additional pores on the pore wall of the absorbent. In order to achieve the desired characteristics of wettability, hydrophobicity, and oleophilicity, the system was preferably functionalized with fatty acids. This allowed the system to be adapted for instantaneous oil absorption due to the combined effect of surface structure and hydrophobicity/oleophilicity of said surface modified absorbent. The aforesaid system is a suitable sorbent not only for recovering crude oil but also for other types of oils due to its brilliant surface functionality paired with hydrophobicity/oleophilicity. Furthermore, the disclosure is made from readily available and inexpensive market components, making it most feasible, cost-effective, and convenient.

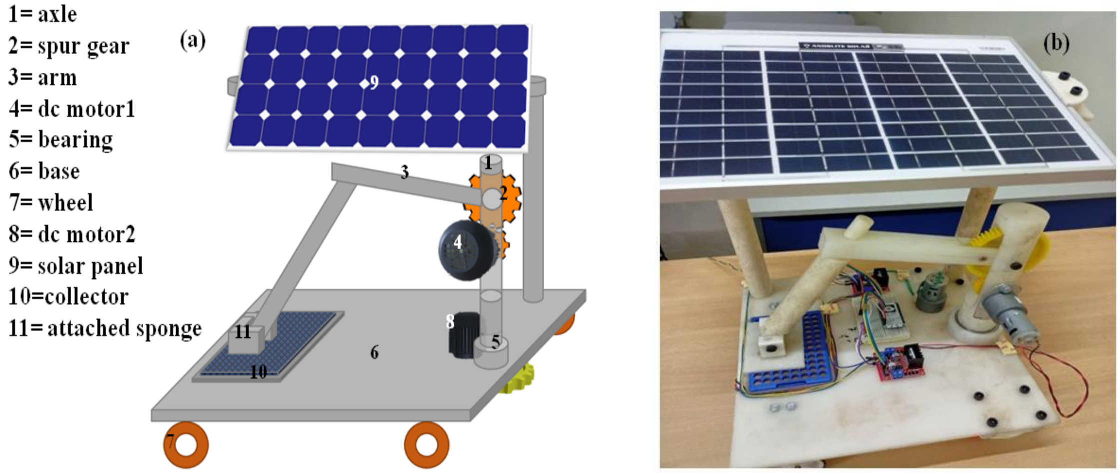

Figure 22. (a) Sketch of the model, (b) complete Setup of the Device.

Development of the device: The device is designed using the cost-effective materials. A nylon board of dimension (300 x 300 x 6) mm is used to construct the base of the device. A cylindrical solid nylon rod (diameter = 45 mm) is used to make the axle of the mechanical arm. The bottom part of this rod is carved out and is inserted through a steel bearing (internal diameter = 25 mm; external diameter = 52 mm) which is then fixed to the base of the device. A pair of spur gear(I) is fixed to the bottom of the device base, which is then connected to the axle through the steel bearing. The mid portion of the axle is carved out so as to fix another pair of spur gear (II). A cubical solid nylon rod of smaller diameter is fixed with this spur gear (II) with nuts and bolts. To the other end of the cubical nylon rod a cross section is being cut out by drilling process to which another cylindrical rod (25 mm) is fixed. At the tip of this nylon rod an arrangement is made where 2D nanomaterial absorbent are attached. A collector box is placed on the base opposite to the axle where the oil collected from the oil spill were stored. A solar panel (10 watt) is added to the device which is fixed at an inclined position with the help of two long vertical stands. On the lower side of the base two pairs of wheels are attached. One pair of robotic wheels attached to the base using aluminum clamps, to which two 12 volt DC motors are attached; and a pair of rotating wheel is used facilitating the device to move in all possible directions.

Working of the device:

After the circuit is complete, the device is now in active state (LED indicator of the microcontroller is ON). The ESP-8266 is programmed to create an UDP server such that it is able to listen to incoming connection requests and messages from established connections. The ESP8266 server creates a Wi-Fi access point such that nearby devices (e.g. Smartphone) can connect to it. After securing a proper connection, it is shown as “CONNECTED” in the app interface and now the user can operate the device. At the app interface there are six buttons (UP, DOWN, LEFT, RIGHT, FORWARD, BACKWARD). The user needs to press any of the buttons available on the BLYNK app interface in order to perform a particular task. When the buttons are pressed, the signal from is forwarded to the microcontroller. On behalf of the received signal the microcontroller decides which pins to activate by sending its output to the motor driver module such that the motor responsible for the desired task is turned on. If the operator presses FORWARD/BACKWARD button available at the app interface, then the pins connected to the motor responsible for the that particular movement will be turned on and the other pins will be turned off. Similarly, if the operator presses LEFT/RIGHT/FORWARD/BACKWARD buttons, then the motors responsible for the particular movement will be turned on. The user can also control the speed of the motors using the speed scrollbar available at the app interface. In practical situation, assuming the arm (with the sponges attached to it) is on top of the collector container, the user will press UPWARD to lift the arm, then towards RIGHT to rotate the axle clockwise. Now, the arm will be over the oil spilled ground. Now by pressing the DOWNWARD, the sponges on the arm will be in contact with oil, where it will start absorbing the oil. After it completely absorbs the oil, the arm will be lifted upwards and the axle will rotate anti-clockwise towards its initial position. After that, the arm will be moved downward over the sieves of the collector container. Now, the sponges will get pressed over the sieves and oil will get removed from it. The removed oil will get collected in the container after passing through the sieves. The device completes the oil removal operation in a fixed time duration.

A.13 Device for collection of oil spill on water bodies

As off-shore oil mining and exploration expands, oil spills are becoming a critical threat to the environment and human life, posing a serious crisis and long-term ecosystem harm. As a result, the clean-up of crude oil spill resulting from oil-water mixture is the most difficult environmental challenge that has prompted significant research into effective cleaning techniques. Numerous methods have been applied from decades to solve this problem but a lack of efficient oil removal technology is still persistent.

So, in order to find a solution, a floating mechanical device using conveyor belt is designed using nanomaterial based polyurethane sponges as oil absorbents (Figure 23). The device is made of a conveyor belt to which the sponge is uniformly attached, and it performs the dual function of absorbing the oil from the s pill and then separating it from the sponge in one rotation, with the oil being collected in a vessel attached to one side of the device. It has floating functionality on both sides of the frame, which is a significant advantage over other existing devices. In addition, unlike skimmers, there is less chance of the device becoming clogged with other pollutants during oil spill removal. Additionally, the current prototype can gather oil from oil-water mixture using a range of absorbent materials. Due to its low price and light weight, it is also perfect for use in oil spills on water bodies.

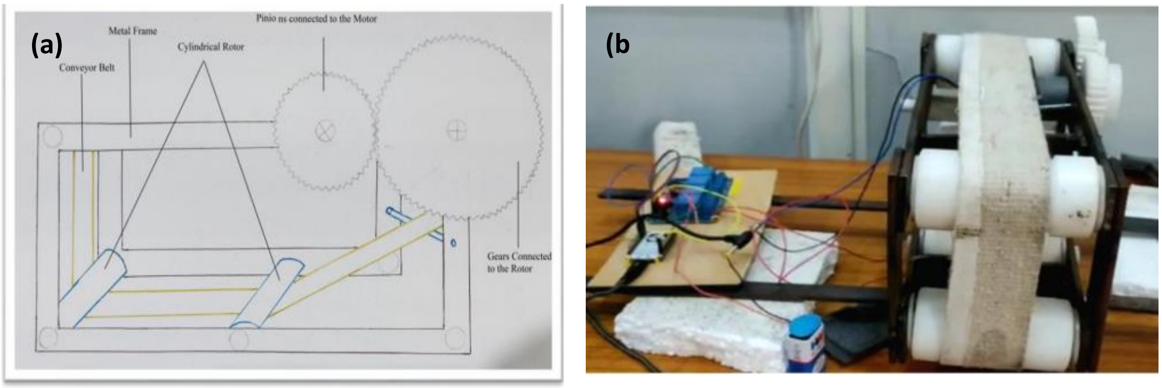

Figure 23. (a) Schematic drawing of the Device (b) Complete Setup of the Device

Design and Fabrication of the Conveyor belt:

Body of the system

The body of the entire system consists of two rectangular frame of dimension 30 mm in length, 10 mm in width and 10 mm in height. The material used in the frame is mild steel. The two frames are joined together by wielded together by putting a metal plate in between.

Cylindrical Rotor

These are the components in the system equivalent to the wheels of a car. Cylindrical rotors are the most effective tools to move the belt. With the help of the kinetic energy generated by the motor, it moves the belt in a linear motion. For a good grip, the surface of the rotors is made rough using a technique called knurling. There are four rotors (R1, R2, R3, R4) with uniform diameter of 51.5 mm are connected in the system. R1 is connected to the gears through an extended shaft. The transfer of angular momentum occurs between the gear and the rotor. The rotor transfers the angular momentum in linear momentum and start moving the belt placed above it.

Spur gear

Spur gears are the most common gears that transmit motion, they are easy to manufacture and suitable for a wide range of applications. As these gears are easy to manufacture, high degree of precision could be achieved during production. Because of their shape, they are classified as a type of cylindrical gears, with shafts that are parallel and coplanar, and teeth that are straight and oriented parallel to the shafts. Due to this, it cannot generate any force in the axial direction and spur gears produce only radial force. The tooth meshing between the gears causes high stress in the gear teeth which results in high noise production. When there are two spur gears in a system in mesh, the gear with higher number of teeth is called gear and the one with lower number of teeth is called pinion. Spur gears can be manufacture from both from metals as well as materials like plastics such as Nylon and Polycarbonate. Gears made by plastic produce less noise. Spur gears have high transmission efficiency as the energy loss is less due to slippage. We can divide spur gears primarily into two categories-

External gear and internal gear. External gears have their teeth cut on the outer surface and the internal gears have their teeth cut in the inner surface of the cylinder. When two internal gears mesh together they move in opposite direction. Two External spur gears are being used for the purpose of transmitting the energy radially from the motor to the cylindrical rotating body. Here, the gear has 44 teeth with a diameter 92.4 mm and the pinion has 30 teeth with a diameter of 64.2 mm. Pinion and gear are connected to the shaft of the motor and the shaft of the rotating cylinder respectively, locked together by a screw.

DC Motor

Dc motor is the type of motor which converts the electrical energy into mechanical energy. The direction of rotation of a motor is given by Fleming's left-hand rule.

Belt

A 50 mm wide Jute belt is used as the conveyor belt in this device. The total length of the belt is 680 mm.

Sponge

It is the major component which collects the oil from the oil spilled fields.

Thermocol

To make the device float in the water we have used Thermocol. These are attached on the both sides to the extended arm of the device. This helps the device remaining afloat in the water while operating.

Development of Electric circuit:

The circuit used for the controlling and power supply of the device is shown in the figure 2. The input terminal (IN1, IN2, IN3, IN4) of the relay module is connected to the digital terminal (D1, D2, D3, D4) of the NodeMCU board. Through this connection the signal sent by the blynk app will reach to the relay module through the ESP8266 board. The VCC terminal of the relay module is connected to the input terminal (Vin) of the NodeMCU board. To power the relay module, we have used a 9 volt battery. It is connected to the relay module through the Ground pin (GND) and JD-VCC pin present in it. One of two terminals present in the switch of relay module is connected to the DC motor and the other is connected to the power supply. The remaining terminal of the DC motor is connected directly to the power supply.

Operation and Control Mechanism

There are various ways of cleaning oil spill, traditional techniques to clean up spilled oil include bioremediation, chemical treatment by dispersants and other physical techniques, but all of them came with their own limitations including high cost and low efficiency. The most effective way in recent developments is cleaning the oil spill using nanomaterial. In AFML Tezpur University has developed one such nanomaterial. To bring this in practical application, we have designed a device. Herein, the focus will be on the operational procedure of the device. It is driven by a DC motor; in one rotation it completes all three steps.

In this three-step process of cleaning the oil spill and extracting the spilled oil, first step is to absorb the spilled oil in a sponge from water. When the circuit is completed the motor starts operating, pinion connected to the motor will transfer kinetic energy to gear which is connected with the cylindrical rotor R1, and hence the conveyor belt starts moving. This device is floating in water with the help of a pair of thermocol, the area of the conveyor belt between the area cylindrical rotor R3 and R4 is in the water level, i.e. when the conveyor pass through this area, sponge will be in contact with water, when a dry sponge pass through this part of conveyor belt sponge will absorb the oil spilled in the vicinity cleaning the water and recovering the lost oil. The conveyor belt can rotate continuously absorbing the spilled oil until the water body is completely clean and oil is fully recovered.

Separation of oil from Sponge:

After absorbing oil from water, the oil remains within the sponge. In the next step this device will separate the oil from the sponge and the sponge will be ready to collect oil for another round of rotation. In the schematic diagram, it is shown that the conveyor belt passes between cylindrical rotor R1 and a small cylinder below it, after crossing the cylindrical rotor R4. After absorbing oil weight of the sponge increases as the oil remains within it & this heavy sponge rotates along with the conveyor belt as it pass through the cylindrical rotors. It can move in two directions one clockwise and another counter clockwise. When it is moving clockwise after passing through the cylindrical rotor R2 it passes between two cylinders (cylindrical rotor R4 & the smaller cylinder placed below), when the conveyor belt is rotating in a counter clockwise the conveyor belt came in contact with these two cylinders after passing through the cylindrical rotor R4. The gap between the two cylinders is placed so that there is enough space for conveyor belt to get passed without any resistance but when the sponge is attached to it squeezes between the two cylinders. As the sponge gets squeezed between the two cylinders, the oil absorbed in the sponge gets released. In this step oil is being separated from the sponge and the sponge is ready for another round of absorption of oil from water.

Collection and Storage of Oil:

After separation of oil from the water the recovered oil should be stored in a vessel. While the sponge gets squeezed between the two cylinders, the oil released get collected in a container placed below it. This container is connected to a vessel placed in the thermocol through a pipe, when the container is half full it transfers oil to the vessel through the pipe and the oil gets stores in the vessel.

Control of Motor through Blynk App

Blynk is a platform that allows to quickly built interfaces for controlling and monitoring hardware project from android or ios device. I have connected the ESP8266 NodeMcu to the application through the mobile wifi. A program to suit our purpose has been modified using the Arduino program. In the program the wifi details of the device to control the motor through the mobile using blynk app. The program is then transferred to the NodeMCU using the programming port.

Blynk app should be downloaded in the mobile phone through which the device will be controlled. NodeMCU is connected to a PC or a laptop, a blynk library is created in the PC with the help of the Arduino application, a programming code is created in the blynk library which contains the user's name and the password of the wifi of the mobile through which it is going to get connected. The signal to operate the motor is sent from the mobile to the NodeMCU through blynk library, from NodeMCU it will be sent to relay module where it responds according to the command given by blynk app.

9. Summary:

The majority scenarios for future global energy predicts that energy demand will triple over the twenty-first century. In this conventional future scenario, the need to extract crude oils is expected to increase in order to replace its declining production. Therefore, it is worth to think about novel technological solutions for rapid and efficient oil recovery. In this regard, adsorbents with nanotechnology based engineered surfaces are a realistic alternative to the limitations of traditional methods used for oil recovery. In such conditions, porous materials combined with functional nanomaterials can be considered as suitable materials for oil recovery. Simultaneously, innovative environment friendly technologies are in high demand for preserving the existing energy resources for future. To overcome this global challenge, we have developed different types of 2D systems with high surface area owing to its 2D sheet structure and porosity, for safe, efficient and rapid removal of oils from water bodies. These studies have reported magnetic hydrophobic/oleophilic graphitic nanosheets exhibiting excellent oil sorption performance and instantaneous removal of adsorbed oil with/without magnetic field. The brilliance of combined surface structure with hydrophobicity/oleophilicity and magnetic functionality through comprehensive adsorption kinetics and inclusive isotherm studies has marked these systems as ideal sorbent for oil recovery. Moreover, we developed 2D based PU sponge engineered with stearic acid (SACSPUS) which exhibited high absorption capacity (99.58%) with quick absorption due to the presence of better internal connectivity (ODHC) and appropriate pore size contributing to the capillary pressure through pore wall of SACSPUS. In addition, two remote controlled prototypes with SACSPUS absorbents were designed, which has a likelihood of being used in large-scale oil spill clean-up.

10. Details of new leads obtained

World's energy consumption will increase by as much as 50% in the next 20 years and global demand for energy is continuously anticipated to increase over the next few decades. The chase to develop new diverged technologies that can address the challenges currently facing by the industries is on high claim. Innovation in oil exploration and enhanced oil recovery (EOR) technologies will be required to meet future demand and hence the Oil and Gas industry will inevitably have to focus on development of new technologies via research and technological innovation to increase the oil recovery of currently producing reservoirs as well as unconventional oil and gas resources. The wastage of oil during drilling not only leads to compromisation on future fuel consumption, but also creates significant threats to environment and human health. In addition, even relatively small oil spills can cause major environmental and economic harm, depending on location, season, environmental sensitivity, and type of oil. Hence, the prominent recovery of spilled oil from oily-water is an important concern.

Nanotechnology has emerged as an alternative technology for *in situ* heavy oil upgrading and recovery enhancement. Nanotechnology with Two Dimensional (2D) nanomaterials provides a promising approach to such innovation. Porous materials combined with functional nanomaterial can be considered as suitable materials for oil recovery due to its properties such as wettability, improve mobility ratio, or control formation without agglomeration. Crude Oil is one of a major producer as well as consumer of energy. In order to match the rapid growing consumption and to balance the future demand of energy, recovery of drilled oil from oil-mud mixture is an important concern and should be improved.

To do so, we turned to 2D nanomaterial incorporated with magnetic materials for inspiration. Two Dimensional (2D) nanomaterials with large surface area having graphitic and irregular number of pores that is suitable for trapping and adsorption of oil into it. Moreover there are holes and cave type openings on the surface that access more surface area available for adsorption. Changing surface wettability of the material from hydrophilic to hydrophobic, the system shows attraction towards oil repelling water. Apart from its adsorption property, 2D materials are promising cost effective and environmentally friendly. Magnetically separation of the crude oil on the other hand helps in production of high quality oils that meet pipeline and refinery specifications. Besides, the adsorbed oil can be recovered without harming or creating any damage to the environment. Thus, we anticipate that all the prepared 2D systems will act as promising adsorbent material for efficient oil recovery and hence provide feasible solution towards the upcoming oil consumption.

Oil spills are a major problem, and when they occur on a large scale, they have disastrous consequences for the environment, human health, and the economy. As a result, there is a need for a method that recovers oil without destroying it or harming the environment. Several oil removal techniques have been used over the last few decades, but they are inefficient. Therefore, this is a great opportunity to develop innovative technology to remove oil from spilled areas in a sustainable and cost-effective manner. We believe that our developed prototype will demonstrate an approach to achieving the oil conservation target.

11. List of papers published along with impact factor (if any):

International

1. Meenakshi Talukdar, Sushant Kumar Behera and Pritam Deb, "Graphitic carbon nitride decorated with $FeNi_3$ nanoparticles for flexible planar micro-supercapacitor with ultrahigh energy density and quantum storage capacity", *Dalton Trans*., 2019, 48, 12137. (**Impact Factor 4.569 and citation index 6.7**).

2. Sushant Kumar Behera, Mayuri Bora, Sapta Sindhu Paul Chowdhury and Pritam Deb, “Proximity effects in graphene and ferromagnetic $CrBr_3$ van der Waals heterostructures”, *Phys. Chem. Chem. Phys*., 2019, 21, 25788. (**Impact Factor 3.676 and citation index 6.3**).

3. Mayuri Bora and Pritam Deb, “Magnetic Proximity Effect in two-dimensional van der Waals heterostructure” *Journal of Physics: Materials*, 2021, 4, 034014. (**Impact Factor 5.847 and citation index 5.8**).

4. Meenakshi Talukdar, Oishik Nath and Pritam Deb, “Enhancing barrier properties of biodegradable film by reinforcing with 2D heterostructure”, *Applied Surface Science* 2021, 541, 148464 (**Impact Factor 6.182 and citation index 8.7**)
5. Meenakshi Talukdar, and Pritam Deb, "Recent progress in research on multifunctional graphitic carbon nitride: An emerging wonder material beyond catalyst", *Carbon* 2022 (**Impact Factor 11.307 and citation index 17.4**).

6. Monika Sharma, Meenakshi Talukdar, Oishik Nath and Pritam Deb, “High connectivity hierarchical porous network of polyurethane engineered by nanoflakes for proficient oil recovery,” *Applied Surface Science* 2022, 601, 154210 **(Impact Factor 7.392 and citation index 12.1**).

7. Mayuri Bora, Sushant Kumar Behera, Prasanjit Samal, and Pritam Deb, "Magnetic proximity induced valley-contrasting quantum anomalous Hall effect in a graphene-CrBr3 van der Waals heterostructure", *Physical Review B* 2022, 235422 (**Impact Factor 3.78**).

8. Meenakshi Talukdar, Sushant Kumar Behera, Subrata Jana, Prasanjit Samal, and Pritam Deb, "Band alignment at heterointerface with rapid charge transfer supporting excellent photocatalytic degradation of methylene blue under sunlight", *Advanced Materials Interfaces* 2022, 2101943 (**Impact Factor 6.389 and citation index 9.1**).

9. Mayuri Bora and Pritam Deb, “Proximity induced longitudinal and transverse thermoelectric response in graphene-ferromagnetic $CrBr_3$ vdW heterostructure”, *Journal of Physics: Condensed Matter* 2023, 35, 055402 (**Impact Factor 2.745 and citation index 4.3**).

10. Meenakshi Talukdar, Raviprasad Kuthethur, Soumyabrata Banik, Nirmal Mazumder, Sanjiban Chakrabarty, and Pritam Deb, "Biocompatible graphitic carbon nitride based fluorescent probe for imaging of breast cancer cell”, *Materials Letters,* 2023, 333, 133674 (**Impact Factor 3.574 and citation index 6**).

11. Monika Sharma, Pulickel M. Ajayan, and Pritam Deb, "Quantum Energy Storage in 2D Heterointerfaces", *Advanced Materials Interfaces* 2023, 10, 2202058 (**Impact Factor 6.389 and citation index 9.1**).

12. Mayuri Bora, Saransha Mohanty, Anil K. Singh and Pritam Deb, "Adaptive Half-metallicity via magnetic proximity in an electrically sensitive 1T'-WTe_2/$CrBr_3$ vdW heterostructure", *Applied Surface Science*, 2023, 623, 157019. **(Impact Factor 7.392 and citation index 12.1**).

National

1. Mayuri Bora and Pritam Deb, "Density Functional Theory in Two-Dimensional Quantum Materials", Indian Journal of Theoretical Physics 2022, Vol. 70 Nos. 1, 2 (ISSN: 0019-5693).

13. Details of mentorship (Masters, PhD, Postdoc, Students guided during the fellowship tenure, training programme, workshop conducted and number of participants etc.):

Masters students:

1. Niyorjyoti Sharma (2019-2020)
2. Sasanka Jyoti Gogoi (2019-2020)
3. Nitumoni Konwar (2020-2021)
4. Manas Chetry (2020-2021).
5. Meethi Buragohain (2021-2022)
6. Priyanka Nath (2021-2022)
7. Sudhanshu Sekhar Sahoo (2021-2022)

Ph. D. students: 1. Bhagyalakhi Baruah (2015-2023)
2. Meenakshi Talukdar (2017-2023)
3. Mayuri Bora (2017-2023)
4. Korobi Konwar (pursuing)
5. Kashmiri Baruah (pursuing)
5. Monika Sharma (pursuing)
6. Saransha Mohanty (pursuing)
7. Liyenda Gogoi (pursuing)
8. Sayoree Purakayastha (pursuing)
9. Anil Kumar Singh (pursuing)
10. Deepshekhar Roy (pursuing)

14. Number of patents filed/granted (National and International) (if any):

1. "2D graphitic sheet for viscous oil removal", Pritam Deb and Meenakshi Talukdar (**Patent Application no. 201831009592**).
2. "Two dimensional heterostructure based composite films for food packaging", Pritam Deb and Meenakshi Talukdar (**Patent Application no. 201931014698**)
3. "Remote controlled device for collection of oil from the oil spill on land", Pritam Deb, Monika Sharma and Nitumoni Konwar (**Patent appl. no. 202131055185**).
4. "Device for sensing and collection of Oil spill on water bodies" Pritam Deb, Monika Sharma and Manas Pratim Chetry (**Patent appl. no. 202131054965).**

15. Technology Developed (if any):

1. "Remote controlled device for collection of oil from the oil spill on land"
2. "Device for sensing and collection of Oil spill on water bodies"

16. Any other information:

Conference presentations

1. "Development of novel and smart 2D heterostructure based nanocomposite film for sustainable food packaging" by M. Talukdar and P. Deb presented at 27th Indian Convention of Food Scientists and Technologists "Raising Agro-processing & Integrating Novel Technologies for Boosting Organic Wellness", 30th January - 1st February 2020,Tezpur University Tezpur University, Napaam, Tezpur-784028.
2. "Proficient oil recovery using 2D nanoflakes engineered porous architecture in polyurethane sponge with smart recyclability and reusability" by Monika Sharma, and Pritam Deb Presented at National Conference on Emerging Trends in Materials Science, 17th May 2022, Tezpur University, Napaam, Tezpur-784028.
3. "WS_2/N-rGO Heterostructure With Enhanced Performances For Supercapacitors" by Monika Sharma, and Pritam Deb Presented at 66th DAE Solid State Physics Symposium, 18-22 December 2022, Birla Institute of Technology Mesra, Ranchi, Jharkhand, India.

09/05/2023

(P. Deb)

Dr. P. DEB
Professor
Dept. of Physics
TEZPUR UNIVERSITY
(Central University)

Principal Investigator,
Tezpur University (Central University)
Date:
Place:

Utilisation Certificate

(For the financial year ending 11th September 2021 to 31st March 2022)

(Rs. in Lakhs)

1. Title of the Project/Scheme: Efficient Oil Recovery as Conventional Energy Using Smart Graphitic Nanocomposite

2. Name of the Organisation: Tezpur University

3. Principal Investigator: Prof. Pritam Deb

4. Deptt. of Biotechnology sanction order No. & date of sanctioning the project: SAN No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022

5. Amount brought forward from the previous financial year quoting DBT letter No. & date in which the authority to carry forward the said amount was given: Rs. 4216/-

6. Amount received from DBT during the financial year (*please give No. and dates of sanction orders showing the amounts paid)*: Rs. 495784/-

7. Other receipts/interest earned, if any, on the DBT grants: Rs. 15/-

8. Total amount that was available for expenditure during the financial year (Sl. Nos. 5,6 and 7): Rs. 500015/-

9. Actual expenditure (excluding commitments) incurred during the financial year (statement of expenditure is enclosed): Rs. 3609/-

10. Unspent balance refunded, if any *(Please give details of cheque No. etc.)*: NIL

11. Balance amount available at the end of the financial year: Rs. 496406/-

12. Amount allowed to be carried forward to the next financial year vide letter No. & date: Rs. 496406/-

Certified that the amount of Rs. 3609 mentioned against col. 9 has been utilised on the project/scheme for the purpose for which it was sanctioned and that the balance of Rs. 496406 remaining unutilized at the end of the year has been surrendered to Govt. (vide No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022) will be adjusted towards the grants-in-aid payable during the next year.

Certified that I have satisfied myself that the conditions on which the grants-in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised the following checks to see that the money was actually utilised for the purpose for which it was sanctioned.

Kinds of checks exercised:

1. Vouchers and Books of Account
2. Statement of Expenditure for the year 2021-22
3. Grant-in-Aid Register

(P. Deb)
PRINCIPAL INVESTIGATOR
DBT Project
Tezpur University

Dr. P. DEB
Professor
Dept. of Physics
TEZPUR UNIVERSITY
(Central University)

13/1/23

FINANCE OFFICER
Tezpur University

Finance Officer
Tezpur University

REGISTRAR
Tezpur University

Registrar
Tezpur University

Utilisation Certificate

(For the financial year ending 1st April 2022 to 31th January 2023)

(Rs. in Lakhs)

13. Title of the Project/Scheme: Efficient Oil Recovery as Conventional Energy Using Smart Graphitic Nanocomposite

14.	Name of the Organization:	Tezpur University
15.	Principal Investigator:	Prof. Pritam Deb

16. Deptt. of Biotechnology sanction order No. & date of sanctioning the project: SAN No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022

17.	Amount brought forward from the previous financial year quoting DBT letter No. & date in which the authority to carry forward the said amount was given:	Rs. 496406/-
18.	Amount received from DBT during the financial year (*please give No. and dates of sanction orders showing the amounts paid)*:	NIL
19.	Other receipts/interest earned, if any, on the DBT grants:	Rs. 2673/-
20.	Total amount that was available for expenditure during the financial year (Sl. Nos. 5,6 and 7):	Rs. 499079/-
21.	Actual expenditure (excluding commitments) incurred during the financial year (statement of expenditure is enclosed):	Rs. 499079/-
22.	Unspent balance refunded, if any *(Please give details of cheque No. etc.):*	NIL
23.	Balance amount available at the end of the financial year:	NIL
24.	Amount allowed to be carried forward to the next financial year vide letter No. & date:	NIL

Certified that the amount of Rs. 499079.00 mentioned against col. 9 has been utilised on the project/scheme for the purpose for which it was sanctioned and that the balance of Rs. 0 remaining unutilized at the end of the year has been surrendered to Govt. (vide No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022) will be adjusted towards the grants-in-aid payable during the next year.

Certified that I have satisfied myself that the conditions on which the grants-in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised the following checks to see that the money was actually utilised for the purpose for which it was sanctioned.

Kinds of checks exercised:

1. Vouchers and Books of Account
2. Statement of Expenditure for the year 2022-23
3. Grant-in-Aid Register

(P. Deb)
PRINCIPAL INVESTIGATOR
DBT Project
Tezpur University

Dr. P. Deb
Professor
Dept. of Physics
Tezpur University, Tezpur- 784028

FINANCE OFFICER
Tezpur University

Finance Officer
Tezpur University

REGISTRAR
Tezpur University

Registrar
Tezpur University

No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022

Statement of Expenditure referred to in para 9 of the Utilisation Certificate

Showing grants received the Department of Biotechnology and the expenditure incurred during the period from 11th September 2021 to 31st March 2022.

(Rs. in lakhs)

Item	Unspent balance carried forward from previous year	Grants received from DBT during the year	Other receipts/ interest earned, if any, on the DBT grants	Total of Col.(2+3+4)	Expenditure (excluding commitments) incurred during in year	Balance (5-6)	Remarks
1	2	3	4	5	6	7	8
1. Non-recurring							
(i) Equipments							
2. Recurring							
(i) Consumables	4216.00	495784.00		500015.00		496406.00	
(ii) Contingency							
(iii) Overheads (if applicable)							
(iv) Interest earned			15		3609.00		
Total Rs.	**4216.00**	**495784.00**	**15.00**	**500015.00**	**3609.00**	**496406.00**	

Total fund utilized
(a) From 11.10.2021-31.03.2022 Rs. 3609.00

Actual expenditure:

Total fund received Rs. 500015.00

Total fund utilized Rs. 3609.00

Balance Rs. 496406.00

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No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022

Statement of Expenditure referred to in para 9 of the Utilisation Certificate

Showing grants received the Department of Biotechnology and the expenditure incurred during the period from 1st April 2022 to 31st January 2023.

(Rs. in lakhs)

Item	Unspent balance carried forward from previous year	Grants received from DBT during the year	Other receipts/ interest earned, if any, on the DBT grants	Total of Col.(2+3+4)	Expenditure (excluding commitments) incurred during in year	Balance (5-6)	Remarks
1	2	3	4	5	6	7	8
1. Non-recurring	496406.00	0.00	2673.00	499079.00		0.00	
(i) Equipments					269297.00		
(ii) Minor Components (Lab renovation)					24190.00		
2. Recurring							
(i) Consumables					119656.00		
(ii) Contingency					85936.00		
(iii) Overheads (if applicable)					0.00		
(iv) Interest earned					0.00		
Total Rs.	**496406.00**	**0.00**	**0.00**	**499079.00**	**499079.00**	**0.00**	

Total fund utilized
(a) From 11.10.2021-31.03.2022 Rs. 3609.00
(b) From 01.04.2022-31.12.2022 Rs. 499079.00

Total Rs. 502688.00

Actual expenditure:
Total fund received Rs. 499079.00

Total fund utilized Rs. 499079.00

Balance Rs. 0.00

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13/2/23

FINANCE OFFICER
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Tezpur University
Registrar
Tezpur University

No. 102/IFD/SAN/3183/2021-22 dated 17.03.2022

Assets acquired wholly or substantially out of Govt. Grants Register to be maintained by Grantee Institution

1. Name of the sanctioning authority: Department of Biotechnology, Govt. of India, New Delhi
2. Name of Grantee institution: Tezpur University
3. No. & Date of sanction order: 102/IFD/SAN/3183/2021-22 dated 17.03.2022
4. Amount of the sanctioned grant: Rs. 495784/-
5. Brief purpose of the grant: Research purpose
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant in aid sanction order. Yes
7. Particulars of assets actually credited or acquired:

Sl.no	Item	Actual cost Rs.
1	Weigh Balance	Rs. 100000.00
2	Computer and 1 Ton Window AC	Rs. 137277.00
3	Revolving Chair	Rs. 20520.00
4	Laminate Sunmica Table	Rs. 24190.00
	Total	Rs. 281987.00

8. Value of the Assets as on 31st January, 2023: Rs. 281987.00
9. Purpose for which utilized at present Research work in university level.
10. Encumbered or not
11. Reasons, if encumbered
12. Disposed of or not
13. Reasons and authority, if any disposal N/A
14. Amount realized on disposal
15. Remarks

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