Rational synthesis and characterization of highly water stable MOF@GO composite for efficient removal of mercury (Hg^{2+}) from water*

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The present study is aimed at adsorptive removal of Mercury (Hg^{2+}) using highly functionalized nanomaterials based on Graphene Oxide Zeolitic Imidazolate Framework composite (ZIF-67@GO). Solvothermal methodology was used to synthesize ZIF-67@GO composite. Synthesized compounds were confirmed by FTIR, SEM, PXRD and EDX analysis. The as-prepared ZIF-67@GO was tested as efficient adsorbent for effective removal of Mercury (Hg^{2+}) from aquatic environment. The atomic adsorption spectrophotometer was used to monitor the process of adsorption of Hg^{2+} on ZIF-67@GO. From the adsorption data, the maximum removal efficiency achieved was 91.1% using 10 mg amount of composite for 50 mL using 20 ppm Mercury (Hg^{2+}) solution. Different parameters like pH, contact time, concentration, adsorption kinetics and isotherm were also examined to explore adsorption process. Adsorption data fitted well for Freundlich Model having R^2 value of 0.9925 than Langmuir isotherm with R^2 value of 0.9238. Kinetics were rapid and excellently described via 2nd order model with R^2 = 0.99946 than 1st order model with R^2 value of 0.8836. Freundlich and pseudo 2nd order models validated that multilayer adsorption process.

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1. Introduction

Water is key to maintain life on the earth. It is necessary to have sufficient amount of drinking clean water to ensure safety to human health. According to international law, access to clean water is the basic human right. Now a days, the availability of clean drinking water is difficult due to water pollution. Both natural and anthropogenic activities are responsible for water pollution. Recently, water pollution has become a serious threat to human beings. According to latest reports, 8 million human beings died every year due to water borne diseases [1]. According to United Nation Agenda 2030, food contamination due to water pollution is one of the most serious global issues which should be resolved as soon as possible [2]. The extensive water solubility of contaminants is responsible for food contamination. The main objective of sustainable development is the frequent access for clean drinking water for everyone [3]. Among water pollutants, heavy metal ions are the emerging water pollutants due to their severe toxicity, persistence, water mobility and accumulation tendency [4]. Heavy metal traces are abundantly found in both sediment and water [5]. Among all heavy metals traces, Mercury (Hg) is volatile and has persistency and therefore can easily transform into other toxic forms leading to bioaccumulation. The “Hg” was the chemical symbol given to mercury which was meaning liquid silver [6]. Environmental Protection Agency (EPA) limited inorganic mercury level up to 144 ppm. EPA suggests that adult with average weight can expose themselves to 0.021 mg of organic or inorganic mercury every day in water or food without any harm. While the Food and Drug Administration (FDA) limited maximum mercury level of 2 ppb in bottled water. The National Institute for Occupation Safety and Health Administration known as OSHA prescribed the minimum limit of 1.2 ppb for organic mercury, 6.1 ppb of maximum mercury level of 2 ppb in bottled water. The World Health Organization (WHO) set the limit of mercury in food stuffs as well. Some of the methods based on the advanced oxidation (AOP) and adsorption processes using porous materials [11, 23, 24, 25, 26, 27]. These utilized methods exhibited various shortcomings like, high cost, complex procedure, low efficiency, less selectivity and reusability [28, 29, 30, 31]. To date, four processes have been used for the removal of mercury. These methods suffer some limitations as well. These methods along with their limitations are: 1st by filtration/coagulation (using AlSO₄ which precipitates out Hg from water has detection limit), 2nd by activated carbon (remove Hg by adsorption process has limitation because effectiveness depends upon Hg concentration), 3rd by reverse osmosis (by passing water through semi-permeable poly-amide membrane has limitation that this membrane is very expensive) and 4th by lime softening (using Ca(OH)₂ to precipitate out the heavy metal ions from water) [32, 33, 34, 35, 36, 37, 38, 39, 40].

Recently, a new and versatile class of porosity coordination polymers, known as Metal Organic Frameworks (MOFs) and their derived composites have shown promising capabilities for removing emerging environmental pollutants. Their versatility can be accessed from their high water and thermal stability as well as broad range of applications [41, 42, 43, 44, 45, 46]. High water solubility of emerging pollutants is serious in their confinement as most of the compounds prepared for the purpose are water soluble themselves. Therefore, MOFs are prominent candidates for effective removal of emerging pollutants especially heavy metals. MOFs and their composites have shown excellent adsorption capacities for different heavy metals especially Hg²⁺ [47].

From all reported MOFs based functionalized materials for adsorptive removal of heavy metals, one special kind MOFs named as ZIFs (zeolitic imidazolate frameworks) have given favorable adsorption performances for removal of emerging pollutants like heavy metals and organic pollutants due to higher surface areas, thermal and water stabilities [48, 49, 50]. The development of a cost effective, convenient and facile method of preparation to gain modified Zeolitic imidazolate frameworks is necessary for the effective removal of Hg²⁺ from water [51]. For improving adsorption performance, the adsorbent surfaces must be functionalized using different methodologies. Various studies successfully explored the modified materials based on composites of MOFs and graphene oxide. ZIFs have great efficiency for pollutants removal from water when its composite is made with graphene oxide. This functionalized material have been efficiently utilized for confiscation of emerging pollutants including organic and inorganic from water [52, 53]. These outcomes indicated that the graphene oxide and ZIFs composites have higher water and thermal stabilities as compared to simple ZIFs [54]. As per literature, few reports are available on utilization of MOFs based functionalized material composites for confiscation of Hg²⁺ from water. A few reports are summarized in Table 1. Therefore, this study aimed at the synthesis of graphene oxide zeolitic imidazolate metal organic frameworks composites using solvothermal methodology and was applied to examine the adsorption capability of as-synthesized composite for removal of Hg²⁺. We proposed that this study will facilitate young researchers to explore their vision in developing strategies for removal of toxic pollutants from aquatic environment.

2. Materials and methods

2.1. Materials used

Hydrochloric acid, Sodium hydroxide, sulphuric acid, 2-methyl imidazole, Graphite powder, cobalt nitrate hexahydrate, potassium permanganate and methanol were of analytical grade and purchased from SIGMA-ALDRICH, Steinheim, Switzerland.
2.2. Methods

2.2.1. Method for preparation of GO

Graphene Oxide (GO) was synthesized using 1 g graphite powder by using Hummer’s method. Practically, 1 g of graphite (powder) having size < 20 μm was taken in 250 mL. About 23 mL of sulphuric acid (H₂SO₄) was mixed dropwise into system which was maintained at 0 °C under vigorous stirring. About 3 g of KMnO₄ was mixed very slowly into mixture under vigorous stirring. The mixture obtained was then shifted to a fixed temperature (40 °C) maintained in oil bath with vigorous stirring for 30 min. After that 50 mL of distilled H₂O added and temperature was increased from 40 to 90 °C. The solution was maintained on stirring for half an hour. After that 150 mL of distilled H₂O and 6 mL of 30% H₂O₂ added to stirring mixture. This addition will result in the color change which leads to foundation of yellowish solution. Resulting solution was left over for some time for decanting obtained product. The obtained solution was then filtered and centrifuged at 6000 rpm for 20 min. The resultant mixture was dried at 60 °C in an oven [55].

2.2.2. Method for the preparation of the composite (ZIF-67@GO)

For ZIF-67@GO synthesis, a 20 mg graphene oxide (GO) was dispersed in 10 mL distilled water (H₂O). Obtained solution was stirred for 10 min to obtain homogenous GO suspension and sonicated for 40 min. Suspension obtained was mixed with solution containing 3 mmol of cobalt salt (Co(NO₃)₂.6H₂O) solution in 10 mL water. Another solution was made by dissolving 2-methyl imidazole (2-MIM) in appropriate amount of water [56]. Solution containing cobalt salt and GO were mixed dropwise in 2-methyl imidazole. Mixture obtained was kept on stirred for 1 h at room temperature. The resulting solution was left overnight for aging and centrifuged at 6000 rpm for 20 min. The product obtained washed with a solution containing CH₃OH & H₂O in 6:4 ratio, several times, to remove unwanted materials. Produced solid product was dried in oven at 80 °C for 12 h [38]. The resultant functionalized nanomaterial was used further to study the adsorption of mercury (Hg²⁺) from water.

2.3. Characterizations

The FTIR analysis of MOFs and composites (ZIF-67@GO) were carried out via ATR technique in 4000-400 cm⁻¹ range using TENSOR-27 (model Bruker-2010) spectrometer. The pH was obtained using SUPH6, pH meter. Absorption analyses were recorded by Atomic Absorption Spectrometer (AAS) (Perkin Elmer Analyst-100) at wavelength of 253 nm wavelength. The SEM (Scanning-Electron-Microscopy) was carried out using Quanta-250 equipped with EDX scanner. The PXRD (Powder X-ray (XD-3)) were used to check morphologies of prepared MOF and ZIF-67@GO.

2.4. Adsorption experiment

Adsorption experiment was carried out using 10 mg amount of adsorbent was added in each solution containing (50 mL) having concentration range of 10–20 ppm. Contact time was 90 min and pH were adjusted by using 0.1 M HCl and NaOH respectively. Adjusted pH was used for the analysis of each and every sample. Initial concentration of 10, 15 and 20 ppm were used with specific adsorbent dose. After performing adsorption experiment, it was found that adsorption process was fast and attained equilibrium after 90 min. This time of 90 min used as equilibrium time. After adsorption experiment, the initial and final concentrations were measured using Atomic Absorption Spectrometer (AAS) [38].

From results obtained from standard solutions, the observed data was applied to calculate the removal efficiency and adsorption-capacity of ZIF-67@GO for Hg²⁺ removal using Eqs. (1) and (2) [57,58]. Moreover, the different parameters effecting adsorption like, pH, contact time, concentration, pseudo 1st and 2nd order, Freundlich and Langmuir model were also studied to explain overall adsorption process.

\[
q = \frac{(C_0 - C_e) \cdot V}{m} \quad (1)
\]

\[
R = \frac{(C_0 - C_e) \cdot 100}{C_e} \quad (2)
\]

where,

\[
C_e = \text{Equilibrium concentration of } Hg^{2+} \text{ (mg/L)}
\]

\[
R = \text{Removal efficiency}
\]

\[
C_0 = \text{Original Hg}^{2+} \text{concentration (mg/L)}
\]

\[
q = \text{Adsorption capacity (mg/g)}
\]

\[
m = \text{amount of adsorbent} \quad V = \text{Volume-of Solution of Hg}^{2+}
\]

The kinetic models i.e., Pseudo 1st and 2nd order applied and value for adsorption capacities were calculated using Eqs. (3) and (4) respectively.

\[
K_1 = \frac{\ln q_e - \ln(q_e - q_t)}{t} \quad (3)
\]

\[
K_2 = \frac{q_t}{t} \left( \frac{1}{q_e^2} + \frac{1}{q_e} \right) \quad (4)
\]

2.5. Determination of point of zero charge

The salt addition method was used to determine the point of zero charge of ZIF-67@GO. The 20 mL solution was taken and initial pH of 0.10 mol/L NaCl was maintained at different pH like 2, 4, 6, 8, and 10 using 0.1 mol/L NaOH and 0.1 mol/L HCl in five different conical flasks. After that, 20 mg of ZIF-67@GO added to each conical flask. The resulting solution mixtures were shaken for 24 h at 25 °C. The resulting

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**Table 1. Maximum adsorption capacities of various adsorbents for mercury (Hg<sup>2+</sup>) removal from water.**

| Sr No. | Adsorbent Used | q<sub>max</sub> (mg/g) | Refs. |
|--------|----------------|------------------------|-------|
| 1      | ACFs-SH        | 11–15                  | [60]  |
| 2      | Ox-MAC and SH-MAC | 35.4                  | [61]  |
| 3      | MWNTs          | 84.66                  | [62]  |
| 4      | 2-MBTZ-FeO₄    | 98.6                   | [63]  |
| 5      | Sulfurized MAC  | 38.3                   | [64]  |
| 6      | GG-cl-CH – N-(CH₂)₆–N–CH-GG | 41.13             | [65]  |
| 7      | POSS-SH        | 12.90                  | [66]  |
| 8      | AL-SH          | 101.2                  | [67]  |
| 9      | ALP            | 107.5                  | [68]  |
| 10     | Polypyrrole-CTs| 40                     | [69]  |
| 11     | Sulfur-functionalized silica | 47.50            | [70]  |
| 12     | BTESPT-SGs     | 93.32                  | [71]  |
| 13     | ATP-APTES      | 90                     | [72]  |
| 14     | ZIF-67@GO      | 131.07                 | This Study |
mixtures were filtered off and final pH of the solution was determined. The pH difference was calculated and plotted against initial pH. When the change in pH is zero then initial pH is equal to point of zero charge that was calculated as 4.8 in case of newly prepared ZIF-67@GO composite (Figure S7) [59]. The ZIF-67@GO composite was positively charged below pH 4.2 (highly acidic media) therefore Hg$^{2+}$ adsorption was inhibited on composite due to H$^-$. The obtained results were subjected to further analysis and it was established that GO having interlayer spacing of 0.74 nm interlayer spacing (obtained from Braggs law using Origin software). Besides, GO peaks were not observed in MOF@GO composites indicating complete exfoliation of GO, full communication and uniform dispersion of GO with assemblies of ZIF-67. The FTIR study was carried out to know GO structural features (Figure S4) that approves the C–C, C–O and C–O–C peaks at about 1540.98 cm$^{-1}$, 1021.73 cm$^{-1}$ correspondingly. While oxygenated groups peaks were reduced because of the GO reduction into rGO in solvothermal synthesis method. The FTIR results for ZIF-67 & its composite (ZIF-67@GO) confirmed synthesis by presence of signal (peak) on 1421.21 cm$^{-1}$ & 1557.13 cm$^{-1}$ correspondingly (Figures S5, S6). Furthermore, to check the adsorptive removal of Hg$^{2+}$ ions, the EDX analysis of ZIF-67@GO composites were also performed before and after the adsorption process. From EDX it is clear that Hg$^{2+}$ ions are successfully adsorbed from water (Figure S7). The factors effecting adsorption process were also examined to have removal efficiency and adsorption capacity of prepared ZIF-67@GO composite. After study it was established that contact time established on 90 min and the 131.07 mg/g adsorption capacity obtained with 91.1 % removal efficiency.

3. Results and discussion

The MOF and the MOF@GO composites were successfully synthesized by following solvothermal method of synthesis. By this method the MOF (ZIF-67) was efficiently grown on the surface of graphene oxide (GO) (Figure 1). After synthesis the materials were subjected to different characterizations in order to check the confirmation of synthesis. First of all, the SEM analysis of MOF and MOF@GO composites were carried out and the results unveiled that ZIF-67 has cubic morphology while the composites SEM showed efficient growth of ZIF-67 on the surface of GO. Figure 2a–2f representing SEM images and it can be established that MOF and MOF@GO composite was successfully synthesized (Figure 2b, 2d). It was observed that, during synthesis, the GO act like surfactant leading to the MOF@GO composite size reduction. After that, the prepared MOF@GO composite was subjected to EDX analysis, the results indicated the elemental composition having following % of 18.95, 15.68, 25.24, 10.3 of C, N, O and Co respectively. While the XRD results revealed the presence of oxygen containing groups on the surface of ZIF-67@GO composite (ZIF-67@GO) confirmed synthesis by presence of signal (peak) on 1421.21 cm$^{-1}$ & 1557.13 cm$^{-1}$ correspondingly (Figures S5, S6).

4. Factors that affect Hg$^{2+}$ adsorption

4.1. The Hg$^{2+}$ concentration effect on adsorption

During adsorption process the effect of Hg$^{2+}$ concentration was checked and it was observed that as the concentration of Hg$^{2+}$ increased from 10 to 30 mg/L then the adsorption capacity value also increased from 95.66 to 131.07 mg/L. This relationship is shown in Figure 3. This whole may be due to the fact that the higher concentration of Hg$^{2+}$ which resulted in greater mass transfer between the liquid and solid phase. The Hg$^{2+}$ removal efficiency reduced from 91.1 % to 59.9 % value by increasing Hg$^{2+}$ amount. The happened due to insufficient availability of active sites of adsorbents or may be due to the active site which got hold on excess in concentration.

4.2. Effect of pH

After knowing concentration effect, the effect of pH on the removal efficiency and adsorption capacity was checked (Figure 4). The highest value 91.1% for removal efficiency was achieved at neutral pH (7.0 ± 1). The presence of various functional group on GO that persist negative charge in pH range of 2–11. So, removal efficiency value surges with pH from acidic pH due to electrostatic interactions between the negatively

Figure 1. Schematic Representation of The Synthesis of Zeolitic Imidazolate Framework (ZIF-67) And Graphene Oxide Metal Organic Framework Composite (ZIF-67@GO) by solvothermal Methodology.
charged composite and positively charged metal ion \( \text{Hg}^{2+} \). While at higher pH metal \( \text{Hg}^{2+} \) still occur in positive form causing repulsion with appropriate parts of MOF@GO composite which resulted in decrease in the removal efficiency from 91% to 59%. This is because the prepared composite has shown removal efficiency at neutral pH. On the basis of results obtained, the pH was efficiently adjusted at 7.0 for accompanying study of \( \text{Hg}^{2+} \) by ZIF-67@GO composite.

4.3. Contact time

The effect of contact time was also noticed for \( \text{Hg}^{2+} \) adsorption on ZIF-67@GO surface. The results of effect of time on adsorption capacity and removal efficiency are indicated in Figure 5a and 5b. It was observed from the results that the value of adsorption capacity increases after 80 min time span and became maximum at 90 min. This was demonstrated as the equilibrium, after that time the adsorption capacity tend to decreases. The increase was due to quick diffusion of metal ions from aqueous solution by ZIF-67@GO composite. End results clearly showed that when the contact time increases the sites availability will also increases and after equilibrium the adsorption decreases due to the metal attachments decrease. The maximum value of adsorption capacity on time of equilibrium obtained as high as 131.07 mg g\(^{-1}\) from aqueous media having 20 ppm \( \text{Hg}^{2+} \) concentration using 10 mg adsorbents.

5. Interpretation of physical models

5.1. Adsorption kinetics

The \( \text{Hg}^{2+} \) adsorption by ZIF-67@GO composite examined by different kinetics for example, pseudo 1st and 2nd order model (Figure 6a and 6b).
Figure 5. Removal Efficiency with time, it can easily be seen that the maximum removal efficiency was achieved at 90 min which is its equilibrium time (a) Adsorption Capacity With respect to Time (b).

Figure 6. Pseudo 1st data not fitted well (a) and 2nd Order which is best fitted in this case (b).

Table 2. Kinetic parameters for pseudo 1st and 2nd order models for MG removal from water using ZIF-67@GO composites.

| Adsorbent Used | Pseudo 1st order Model | Pseudo 2nd Order Model |
|----------------|------------------------|------------------------|
|                | Intercept   | Slope     | R²     | Intercept   | Slope     | R²     |
| ZIF-67@GO      | 5.4288      | -0.03029  | 0.8836 | 0.17166    | 0.00227   | 0.99946 |

R² = Linear correlation coefficient.

Figure 7. Langmuir Model is not fitted well (a) Freundlich Model was fitted well (b).
The value of R² (correlation coefficients) for kinetic models were successfully calculated. The results indicated that correlation coefficient value of 0.9995 for the 2nd order model showed this model was best fitted for the Hg²⁺ adsorption using ZIF-67@GO composite. This showed that chemisorption process involved in determining rate of reaction. This also showed adsorption process occurs because of forces which formed of exchange or sharing of electrons between polar-group like amines and some other metal ions. Results shown in Figure 6b and 6b and are calculations described in Table 2.

### 5.2. Adsorption isotherm

For study of isotherm, the different models like, Freundlich and Langmuir model were applied to have clear adsorption isotherm for Hg²⁺ adsorption by using ZIF-67@GO. The results of adsorption-isotherm studies are given in Figure 7a, 7b, Table 3. Results showed that R² (correspondence correlation coefficient) value for Langmuir-model showed excellent results as compared to Freundlich model. Therefore, Freundlich model (adsorption isotherm having value of 131.07 mg g⁻¹ adsorption capacity) was best suited for explaining the adsorption of metal ion by using the prepared composite (ZIF-67@GO).

### 5.3. Regeneration of adsorbent

The regeneration experiment for the used adsorbent were performed that is important characteristic of MOFs adsorbents which make them superior to the other adsorbent used for the adsorption. For regeneration studies, the mixture of ethanol/HCl in ratios 1:9 utilized as model (standard) desorbing-agents. Subsequently, after regeneration of already used adsorbent, the value of removal efficiency calculated and it was observed that it reduces from 91.1% to 89.9% showing higher reusability even after couple of recycle experiments. These consequences indicated that ZIF-67@GO has shown exceptional removal efficiency and reusability (Figure 8).

### 6. Proposed adsorption mechanism of Hg²⁺ adsorption

The Mercury (Hg²⁺) was successfully consecrated from water on adsorbing surface of graphene oxide-metal organic framework (ZIF-67@GO) due to the availability of inner pores of the surfaces of adsorbent. Adsorption process was reinforced because of high surface area of composite (adsorbent) pores as compared to adsorbate. Results of the kinetic models applied have shown that Reported literature indicated that ZIF-67 with a zeta potential of 6.5 has strong surfaces to trap Hg²⁺ molecules into ZIF-67@GO pores from aqueous media. Some important features like surface (hydrophobic) and electrostatic interaction played their role in mercury (Hg²⁺) consecration. The correlation coefficients Values (R²) for applied models to study adsorption study were also determined. After satisfactory results, it was observed that multilayer chemisorption process/mechanism is elaborate during whole processes for Hg²⁺ consecration via adsorption on ZIF-67@GO composite because of the presence of fine sheets of graphene oxide and highly functional active cites of MOF which was successfully deposited on GO surface. It has already reported that such type of adsorption depends on different

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**Table 3. Isothermal parameters for Langmuir and Freundlich model.**

| Adsorbent Used | Langmuir Model | Freundlich Model |
|---------------|----------------|-----------------|
|               | Intercept     | Slope           | R²  | Intercept     | Slope           | R²  |
| ZIF-67@GO     | 0.0089        | -0.00371        | 0.92385 | 1.51607 | 0.57627        | 0.9925 |

R² = Linear correlation coefficient.
groups of adsorbents surfaces. This provided strongest evidence that our material was successfully synthesized and it has the capacity to adsorb Hg\(^{2+}\) due to electrostatic interaction between the ZIF-67@GO and Hg\(^{2+}\) on ZIF-67@GO surface. After adsorption the EDX analysis were carried out to confirm the adsorption of Hg\(^{2+}\) on the surface of composite. The EDX Results provided evidence for Hg\(^{2+}\) adsorption by MOF@GO composites (Figure S6). It was found during subsequently adsorption experiment that hydrophobicity became troublesome which results in a higher-degree disorder of bulk structure of H\(_2\)O. Projected mechanism of Hg\(^{2+}\) confection using ZIF-67@GO is shown in Figure 9.

7. Conclusion

This study was aimed at confiscation of mercury (Hg\(^{2-}\)) from aqueous media using ZIF-67@GO, prepared using solvothermal method of synthesis. The synthesized compounds were confirmed using FTIR, SEM, EDX and XRD. The adsorption experiment was monitored by atomic adsorption spectroscopy. The prepared ZIF-67@GO were tested as adsorbent for Hg\(^{2+}\) confection and adsorption experiments results revealed that it is efficient for Hg\(^{2+}\) confection. The maximum removal efficiency was 91.1\% using 10 mg of prepared adsorbent material. Effects of pH, Hg\(^{2+}\) concentration, contact time, adsorption kinetics were also studied. Results showed that adsorption study fitted well to Freundlich isotherm with R\(^2\) value of 0.9929 than that of Langmuir isotherm with R\(^2\) value of 0.9238. Kinetics models of adsorption was rapid and best fitted for pseudo 2nd order (R\(^2\) = 0.99946) than 1st order model (R\(^2\) = 0.8836), which indicated that multilayer chemisorption occurs during adsorption process. The highly water stable ZIF-67@GO composites have revealed excellent reusability after many cycles indicating excellent reusability, which indicated that multilayer chemisorption occurs during adsorption process. Consequently, it can be said that prepared ZIF-67@GO composite can efficiently be used for confiscation of Hg\(^{2+}\) from water.

**Declarations**

**Author contribution statement**

Ahmed M. Fallatah: Performed the experiments.
Habib Ur Rehman Shah: Analyzed and interpreted the data; Wrote the paper.
Khalil Ahmad: Performed the experiments; Analyzed and interpreted the data.
Muhammad Ashfaq; Abdul Rauf: Conceived and designed the experiments.
Muhammad Muneer; Zeinom M. El-Bahy: Contributed reagents, materials, analysis tools or data.
Mohamed M. Ibrahim; Afshain Babras: Analyzed and interpreted the data.
Amir Shahzad: Wrote the paper; Contributed reagents materials, analysis tools or data.

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**Data availability statement**

Data included in article supplementary material referenced in article.

**Declaration of interest’s statement**

The authors declare no conflict of interest.

**Additional information**

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