



## Studies on Removal of As(III) by Biomass of *Cymbopogon flexuosus*

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### Abstract

*Cymbopogon flexuosus* (lemon grass) cultivated by farmers for fragrance, oils and folk medicine remediates/ accumulates highly toxic As(III) originating from geological deposits as well as anthropogenic activities. *Cymbopogon flexuosus* contains citral, geraniol, isonerol in addition to several other bioactive compounds widely used for anticancer, antioxidant and antimicrobial properties. Insertion of arsenic in the food chain of human being has become a potential threat to the civilization these days. More than 10 million people of Bihar especially on or near the Gangetic Plain of Bhagalpur district in Bihar are suffering from the effects of arsenic on their body. Activated charcoal has already been reported for the adsorption of arsenic but due to its less efficiency in reusability, bentonite had been used as adsorbent in our previous work. Now, in our present work, *Cymbopogon flexuosus*, a naturally occurring biomass, has been found to act as efficient adsorbent of arsenic. Several parameters such as pH, concentration, dosage have been highlighted in the present work. With increased doses of *Cymbopogon flexuosus* biomass, desorption of As(III) takes place to some extent in the pH range 6.7 – 7.4. The maximum removal efficiency is 52.17% for 2g biomass powder up to 1 hour. The Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) has used for analysis of As(III). Thus, the kinetic study of uptake of arsenic by lemon grass has been done. The land being used for cultivation of lemon grass should contain arsenic and toxic elements well below the permissible limit.

**Keywords:** ICP-AES, *Cymbopogon flexuosus*, Kinetics, Bioactive, As(III).

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### 1. Introduction

Heavy metals such as Hg, Cd, Pb, and Cr are posing a serious threat to the living beings due to their toxicity, non-biodegradability and persistence in soil. In addition, a metalloid, Arsenic in the oxidation states +3 and +5, is causing hyperpigmentation and skin cancer on prolonged use. The Gangetic plain of the country in general and Bhagalpur in particular have rich argillaceous sediments contaminated with As<sup>+3</sup> and As<sup>+5</sup> as a result of which the aquifer of the particular region has greater concentration of arsenic [1-2].

Rocks sediments, ores of metals and coal deposits along with anthropogenic activities contribute to enhanced concentration of arsenic in ground water as well as surface water [3-4]. Several case studies have been done to find the arsenic contamination in ground water and related cases of hyperpigmentation in the Gangetic plain. The studies have shown increased cases of cancer caused due to inorganic arsenicals in the Gangetic plain of Bhagalpur. In addition to arsenic, pesticides and fertilizers used in agriculture are adding to the problem of arsenicals in the Gangetic belt. A

relation between pesticides and recognized carcinogen has been reported in agriculture based population[5-6]. The Gangetic belt has agro-based economy based on the production of maize, wheat and other crops.

Arsenic may enter the food chain and the medicinal plants through soil and irrigation water. Entry in food chain followed by consumption by human is affecting more than 10 million people in Bihar. The metabolism of inorganic arsenicals, ability to induce oxidative stress, DNA damage and disruption of cellular signaling pathways give rise to high carcinogenic potential of arsenic. Depletion of ATP by arsenate through competition for phosphate anion transporters and inhibition of ATP to ADP has been reported in cellular system[7]. Citral, an important monoterpene found in *Cymbopogon flexuosus* has been established as an inhibitor of cancer cells. It suppresses the HSP90 (Heat Shock Protein 90) gene expression, a major chaperone cancer protein[8-9]. Citral inhibits and induces apoptosis in MCF – 7 cells. Medicinal plants also possess the various high remediation potential for heavy metals and arsenic. Colchicum luteum has been reported to be accumulator of Cr(VI) and dyes[10]. Phytoremediation of Cr(VI) and As(III) from aqueous medium by *Cymbopogon flexuosus* has also been reported[11]. Here the dried powder of lemon grass is used for removal of arsenic from aqueous medium. Farmers for aromatic oil cultivate *Cymbopogon flexuosus*, a medicinal and aromatic perennial plant.

It has several medicinal uses such as antioxidant, antimicrobial, anti-inflammatory, anticancer and anti-cholesterol properties. It becomes therefore necessary to grow it on soil free from heavy metals and arsenic. With a view to this, arsenic uptake by the powdered leaves of lemon grass has been studied. Essential oils from lemon grass contain Citral, Geraniol, Myrcene, Isoneral and several other bioactive compounds[12]. Though the methods of ion exchange, electrocoagulation, membrane filtration, agriculture solid mass, zeolites, bentonite along with clay minerals are available, removal by biomass has been explored as an alternative option[13-14]. Clay and clay minerals are found in abundance in different parts of the world [15]. The bentonite minerals of Rajmahal hills range has also been studied for several physical properties and heavy metal remediation potential [16-18]. Arsenic has been removed from aqueous medium by bentonite mineral[19-22]. Activated carbon is also abundantly used for remediation of the heavy metals and arsenic[23]. However, reuse of the disposed activated carbon has put constraints on its use. These problems during the use of these adsorbents have intensified the search for alternative natural waste agriculture product, aquatic weeds and medicinal plants[24-26]. Sugar cane bagasse, rice husk powder, orange peel and several other adsorbents have been used for remediation of arsenic.

Several fern species such as *Pteris pitta*, *Pteris longifolia* have been reported as hyperactive accumulators of arsenic. In addition, *Azolla microphylla*, *Lemna minor* and *Eichhornia crassipes* accumulate arsenic from aqueous medium but some release also takes place after a certain interval of time. Algae cells of *Microcystis aeruginosa* also accumulate inorganic arsenate from aqueous medium[27]. Adsorption removes arsenic from aqueous medium by the interaction of the adsorbate with surface through binding or complexation. Generally, pseudo-first order or second order model is the best-fit or rate-controlling

step during adsorption. Freundlich and Langmuir isotherm models are generally used to see the best fit for experimental data. A plot of  $\log q_t$  versus  $\log C_t$  gives Freundlich isotherm whereas  $\frac{C_t}{q_t}$  versus  $C_t$  gives Langmuir isotherm[28]. Where  $q_t = \frac{C_0 - C_t}{m} \cdot V$ ,  $C_0$  is the initial concentration,  $C_t$  is the final concentration,  $m$  is the mass of adsorbent in g and  $V$  is the volume in liters. The aim is to study the effect of arsenic in drinking water leading to cancer. The essential oil of *C. flexuosus* preventing cancer cell may be harmful due to arsenic uptake.

## 2. Materials and Methods

Live plants of *Cymbopogon flexuosus* has been collected from University Department of Chemistry, Tilka Manjhi Bhagalpur University, Bhagalpur. The root intact plants have been washed with running tap water and then by deionized water. The plant biomass cut into small pieces and air-dried at room temperature. After that, the biomass is kept inside hot air oven at 60°C for 8 hours and then powdered in grinder. Batch operation was designed for leaves biomass of *Cymbopogon flexuosus* for two, four and 6 ppm initial concentrations. The solutions of different concentrations were taken in separate 250 mL conical flasks and 1g, 2g, 3g and 4g of powdered biomass were added separately up to a fixed time interval of 1 hour. 1g biomass of *Cymbopogon flexuosus* was treated with solutions of 2, 4 and 6 ppm concentrations up to 1h, 2h and 3h with a view to study the kinetics of the reaction. The solution was shaken in a magnetic stirrer at 130 rpm for all the batch experiments. The residual concentrations were known from ICP-AES JOBIN YVON (FRANCE) Model Jobin Horiba JY 2000(2) in the wavelength range 170 – 440 nm with photomultiplier R-106 detector. The residual concentrations of As were determined at 193.695 nm. A calibration curve obtained by plotting intensity versus concentration of As in ppm.

## 3. Results and discussion

The removal percentage of As(III) has been determined by the formula.  $\% \text{ removal} = \frac{C_0 - C_t}{C_0} \times 100$ . The maximum percentage removal is 52.17% for 2g biomass powder up to 1 hour (Table – 1). Figures 1(A), 1(B), and 1(C), represent the plots between  $\log q_t$  versus  $\log C_t$ . The linearity in the graphs indicates that Freundlich adsorption isotherm followed. The plots 1(D), 1(E), and 1(F) shows the graphs  $\log q_t$  versus  $\log C_t$  for different biomasses up to 1 hour. Figures 2(A), 2(B), and 2(C) represent the Langmuir isotherm for a fixed biomass up to 1h, 2h, 3h with different initial concentrations whereas 2(D), 2(E), and 2(F) represent Langmuir isotherm for different biomasses. The experimental data fit both with Freundlich as well as Langmuir adsorption isotherms. Figures 3(A), 3(B) and 3(C) show the plot between  $t/q_t$  versus  $t$  up to different time intervals indicating pseudo second order reaction. Figures 4(A), 4(B), and 4(C) show the plot between  $q_t$  versus  $t$ . Figures 5(A), 5(B), and 5(C) establish that the adsorption does not involve intraparticle diffusion. Figures 6(A), 6(B), and 6(C) represent Elovich adsorption isotherm whereas figures 7(A), 7(B), and 7(C) represent the plot between percentage removals versus time. Figure 8 shows the calibration curve.

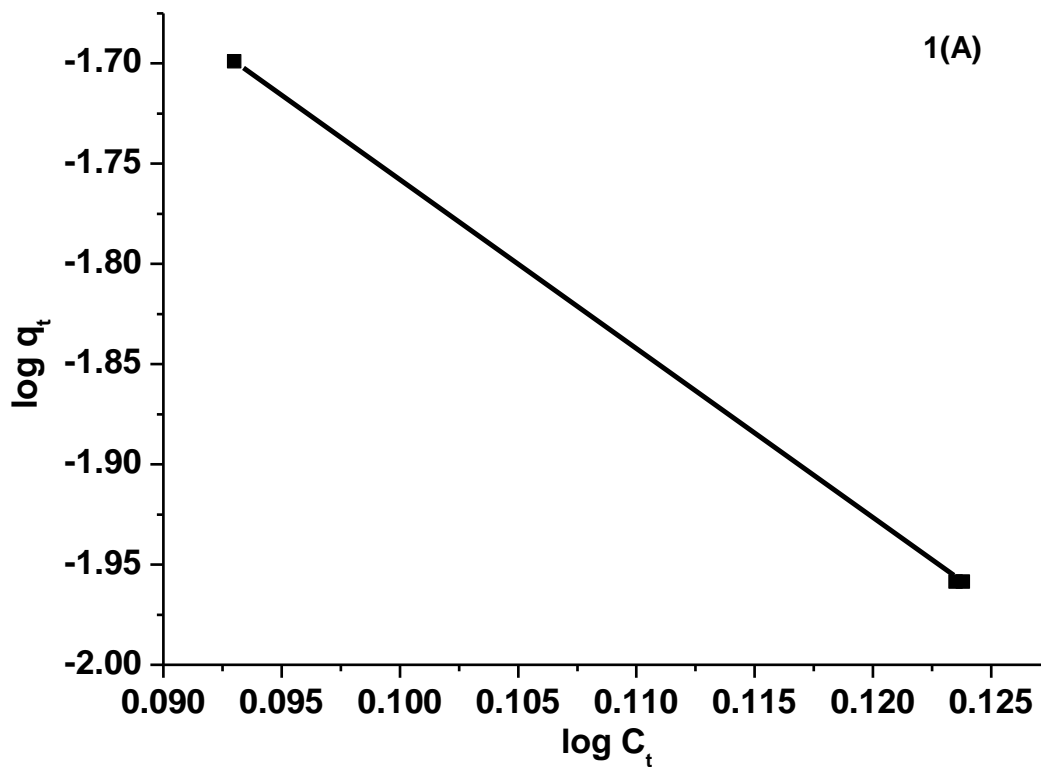


Figure 1(A): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 1.44 ppm at 1h, 2h and 3h

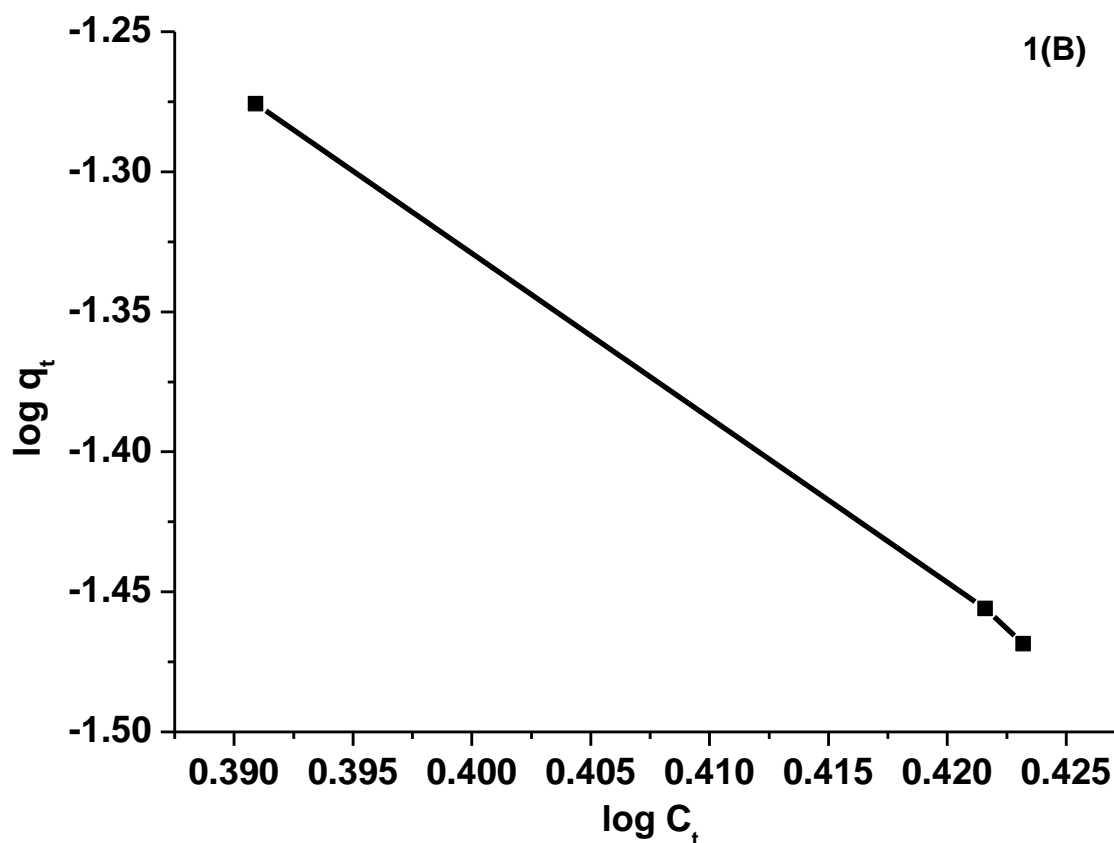


Figure 1(B): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 2.99 ppm at 1h, 2h and 3h

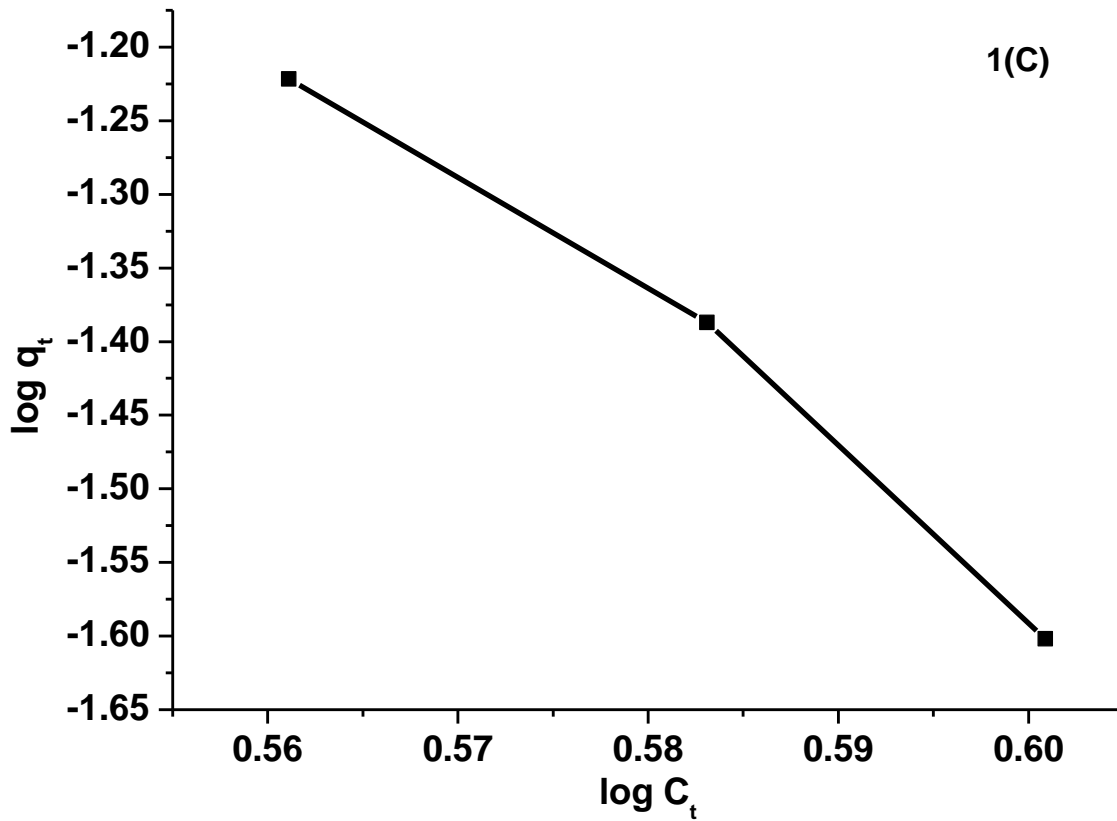


Figure 1(C): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 4.24 ppm at 1h, 2h and 3h

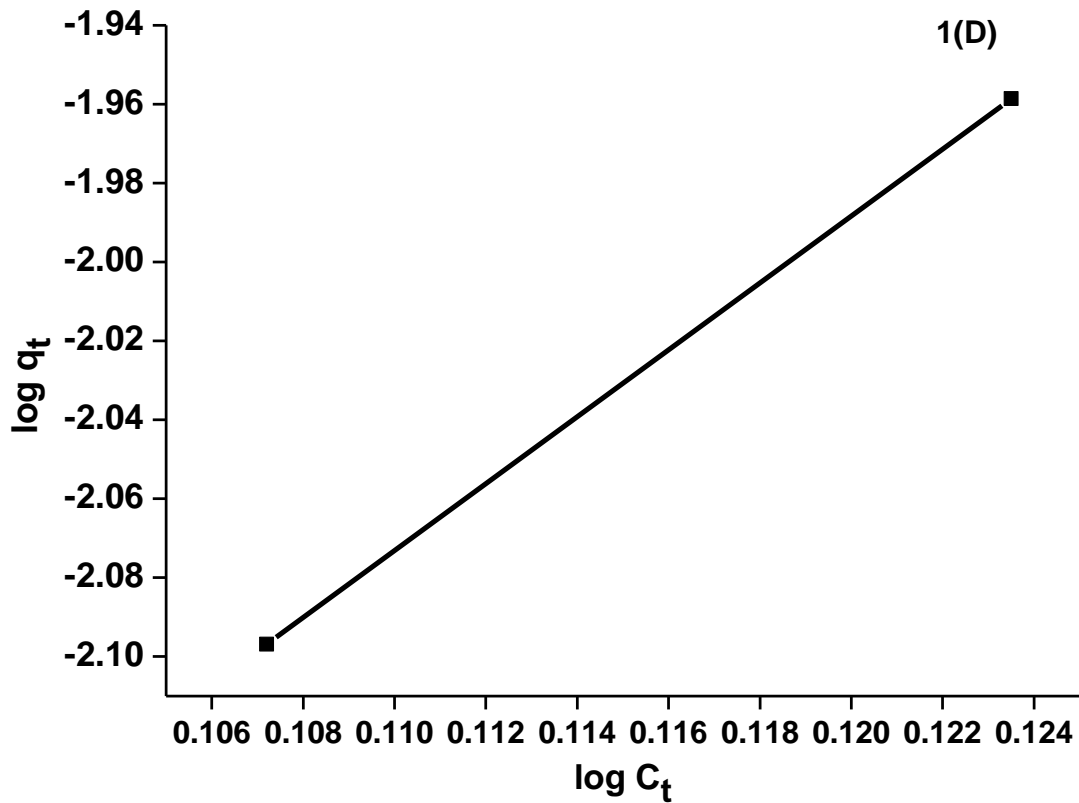


Figure 1(D): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 1.44 ppm and different biomass at a fixed time of 1 hour

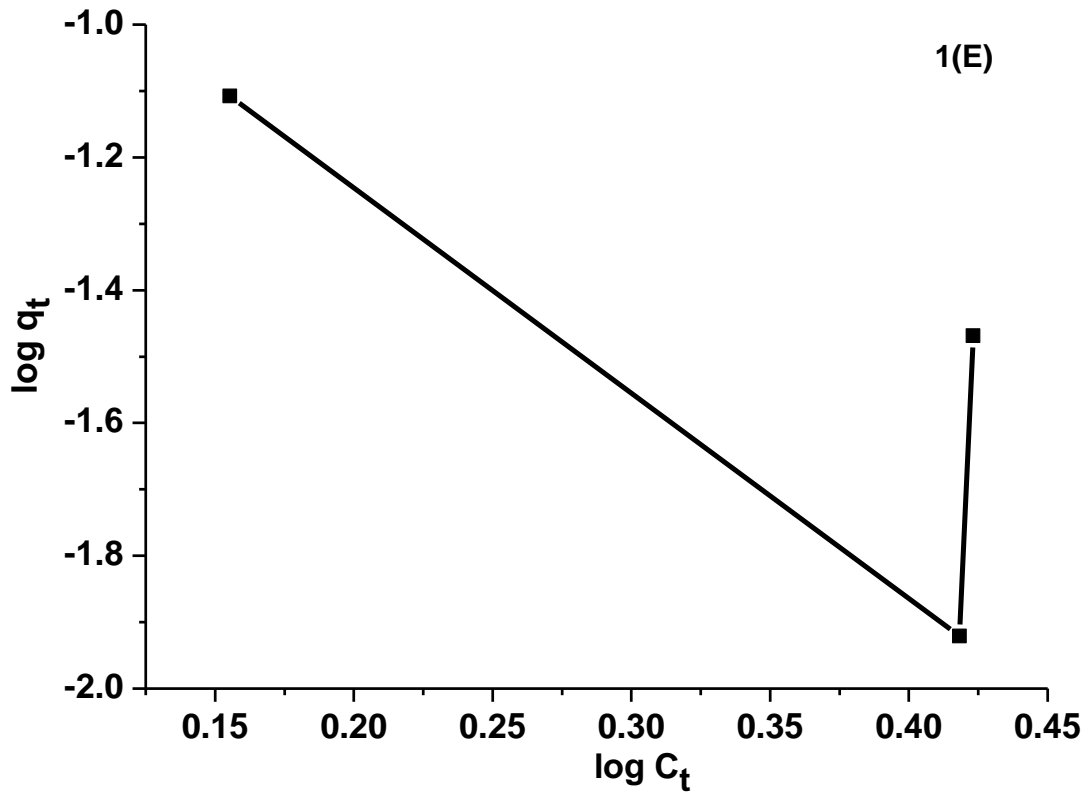


Figure 1(E): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 2.99 ppm and different biomass at a fixed time of 1 hour

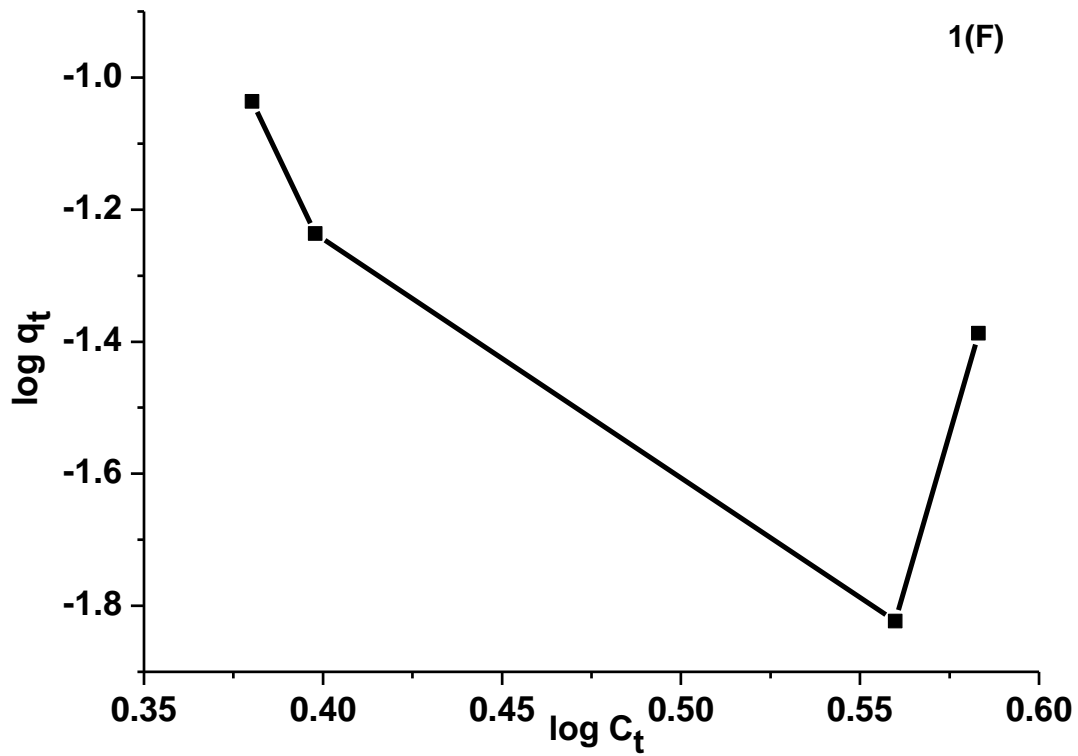


Figure 1(F): Plot of  $\log q_t$  Vs  $\log C_t$  with an initial concentration of 4.24 ppm and different biomass at a fixed time of 1 hour

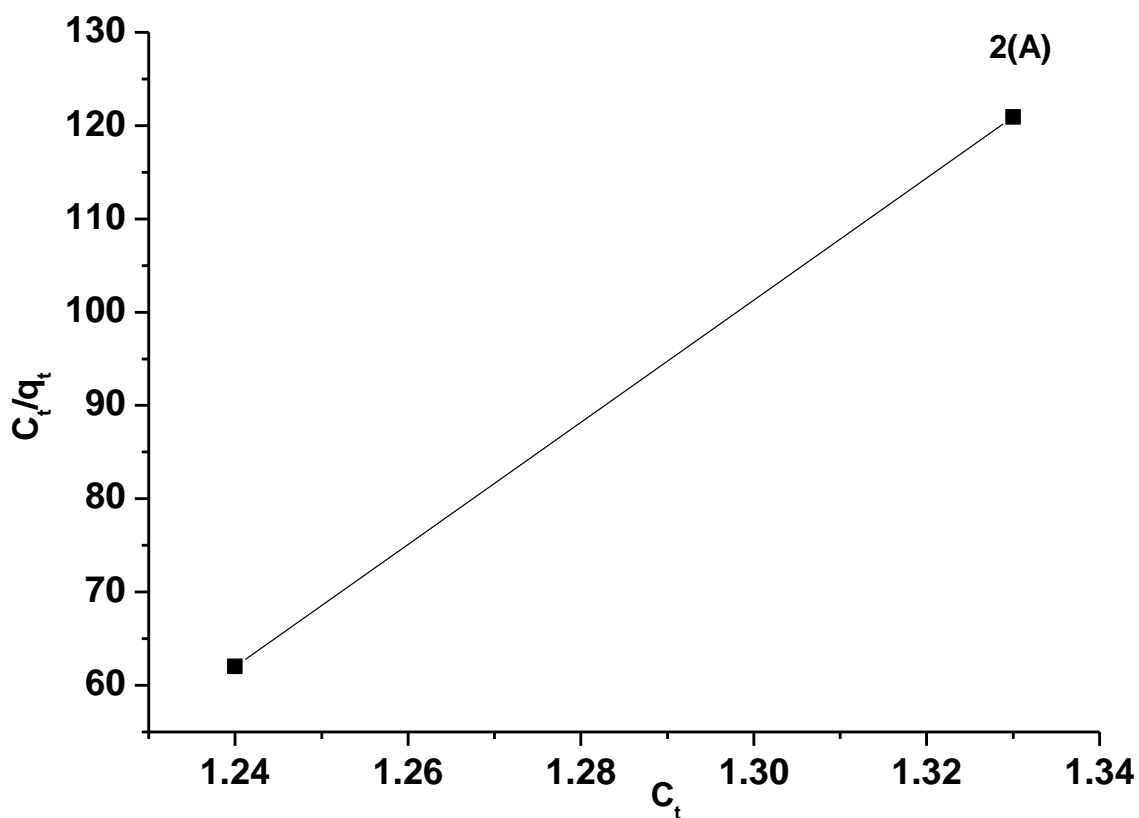


Fig 2(A): Plot of  $C_t/q_t$  Vs  $C_t$  with an initial concentration of 1.44 ppm at 1h, 2h and 3h

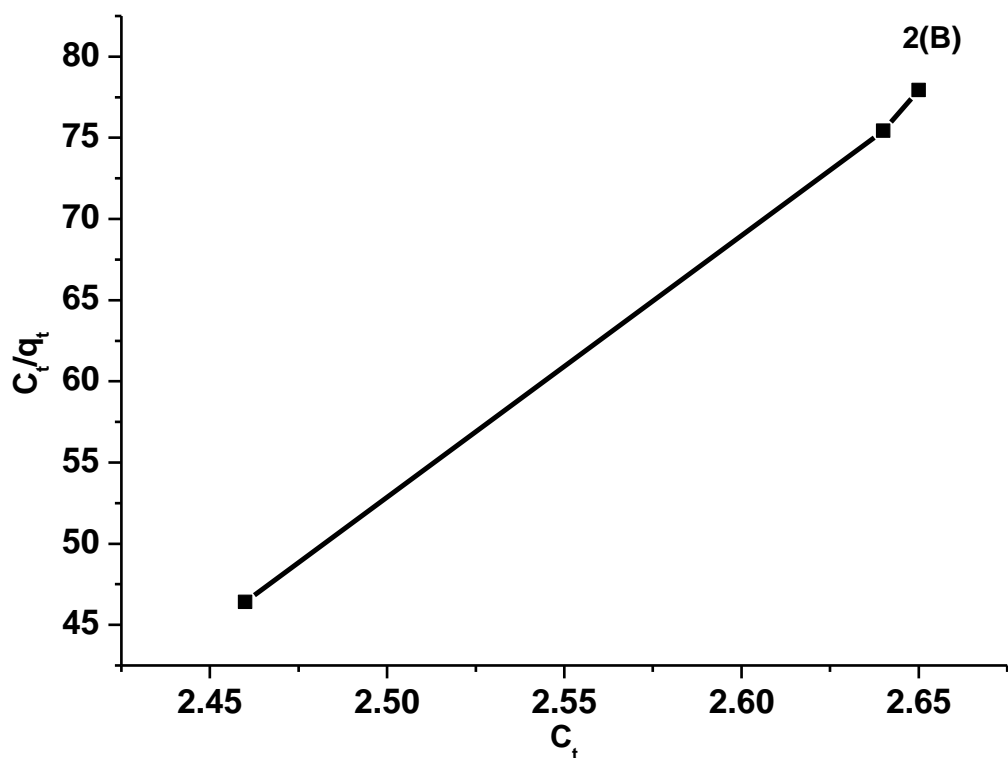


Figure 2(B): Plot of  $C_t/q_t$  Vs  $C_t$  with an initial concentration of 2.99 ppm at 1h, 2h and 3h

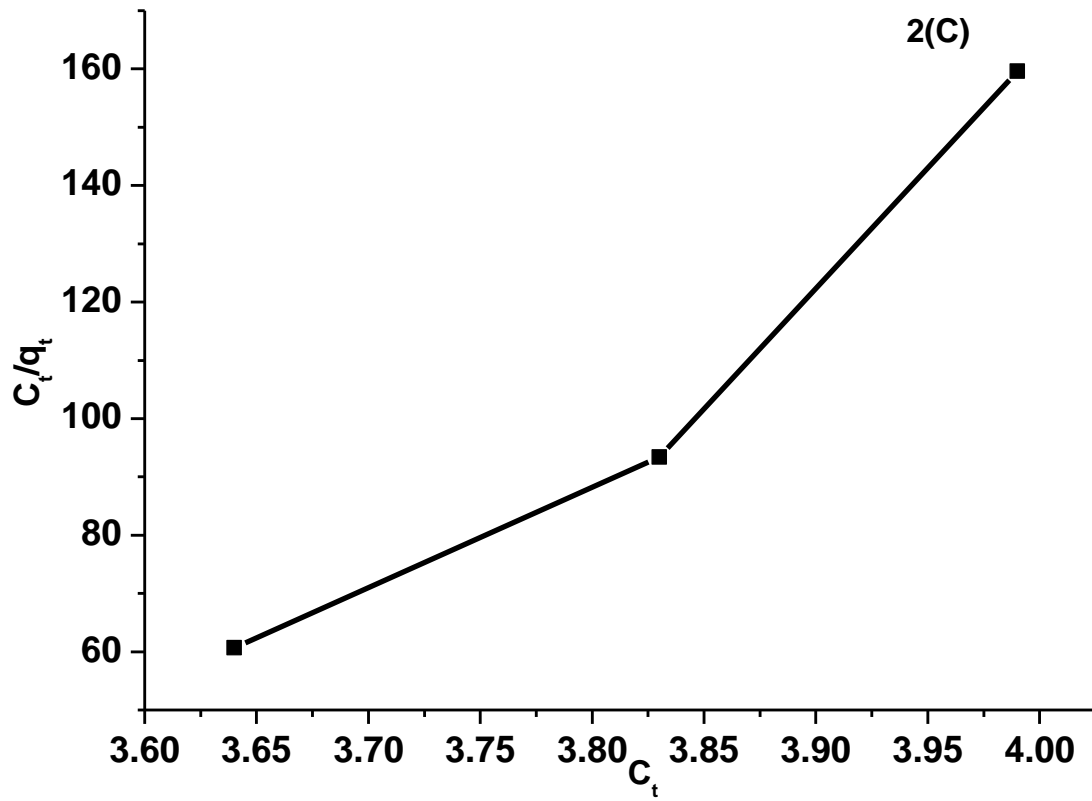


Figure 2(C): Plot of  $C_t/q_t$  Vs  $C_t$  with an initial concentration of 4.24 ppm at 1h, 2h and 3h

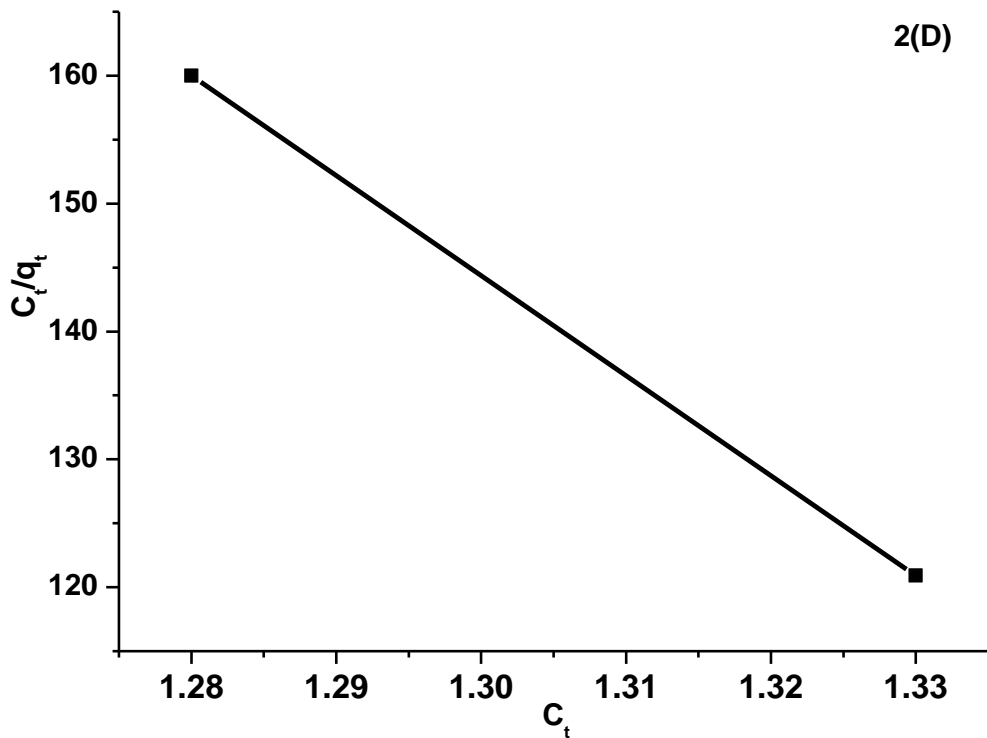


Figure 2(D): Plot of  $C_t/q_t$  Vs  $\log C_t$  with an initial concentration of 1.44 ppm and different biomass at a fixed time of 1 hour

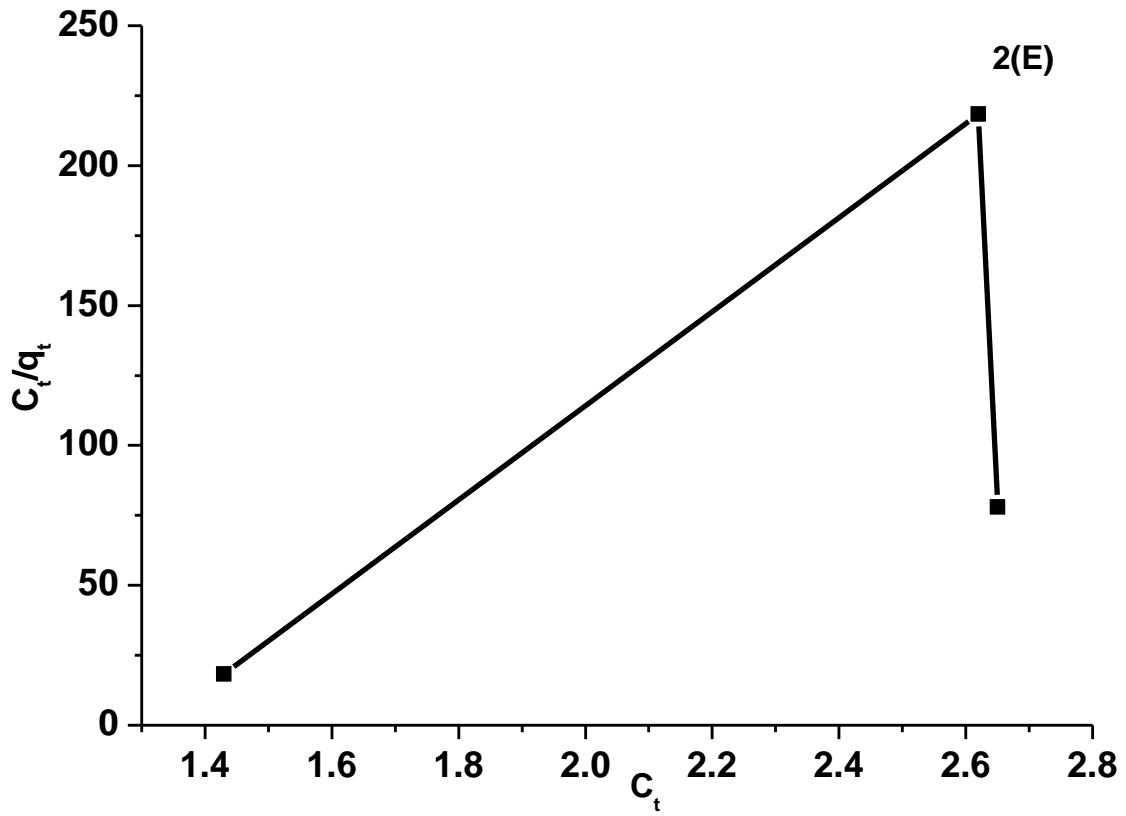


Figure 2(E): Plot of  $C_t/q_t$  Vs  $\log C_t$  with an initial concentration of 2.99 ppm and different biomass at a fixed time of 1 hour

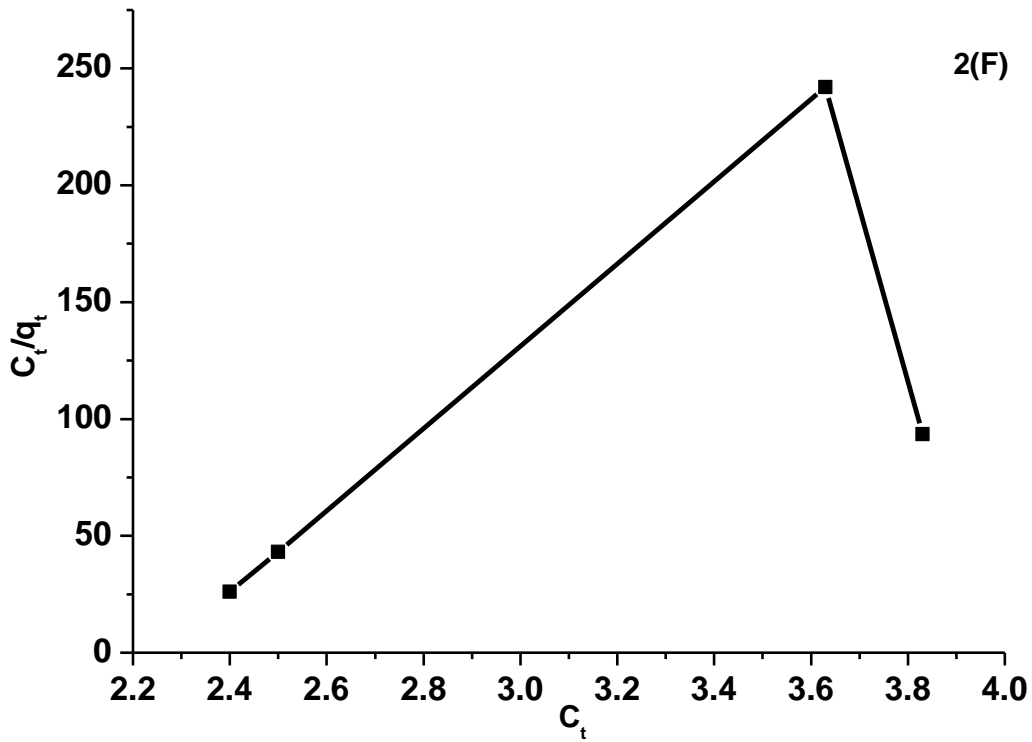


Figure 2(F): Plot of  $C_t/q_t$  Vs  $\log C_t$  with an initial concentration of 4.24 ppm and different biomass at a fixed time of 1 hour



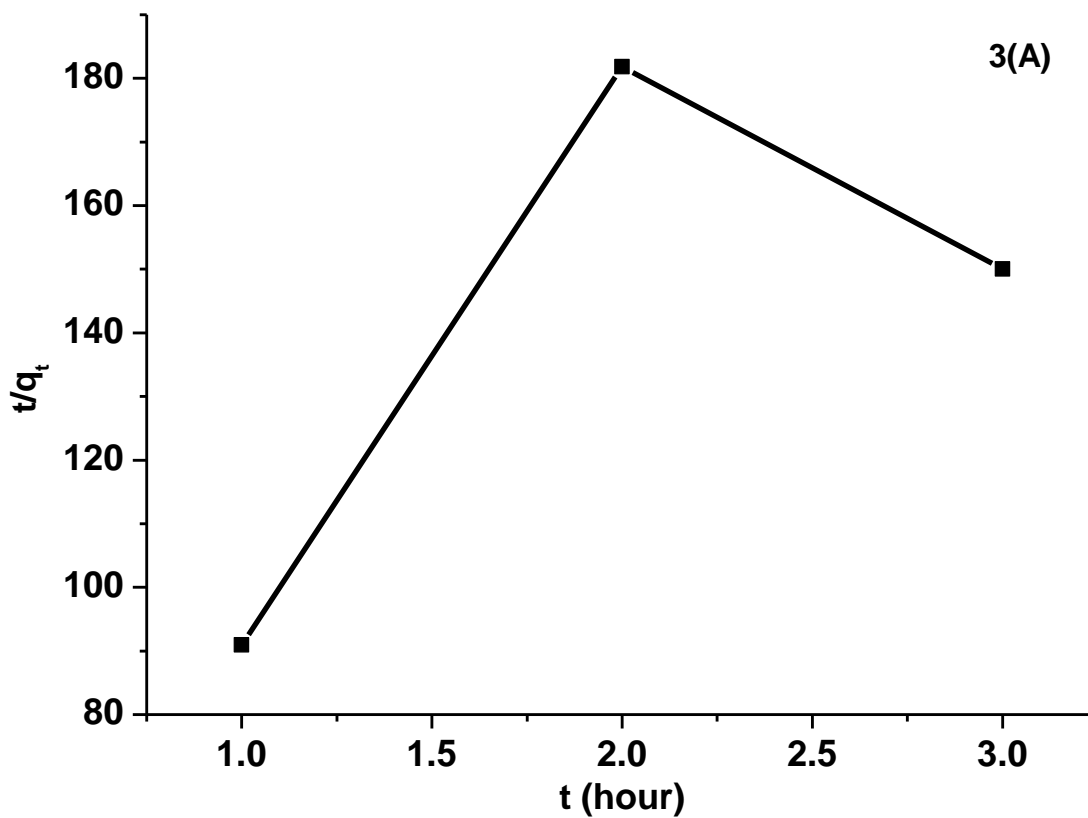


Figure 3(A): Plot of  $t/q_t$  Vs  $t$  with an initial concentration of 1.44 ppm and 1h, 2h and 3h

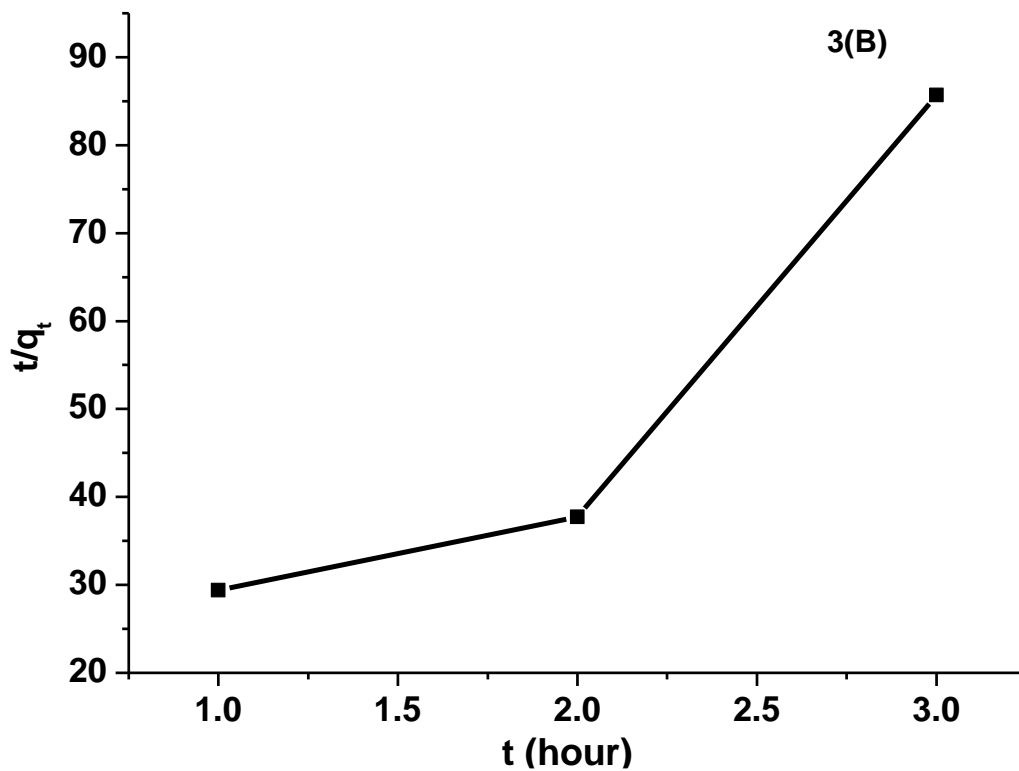


Figure 3(B): Plot of  $t/q_t$  Vs  $t$  with an initial concentration of 2.99 ppm and 1h, 2h and 3h

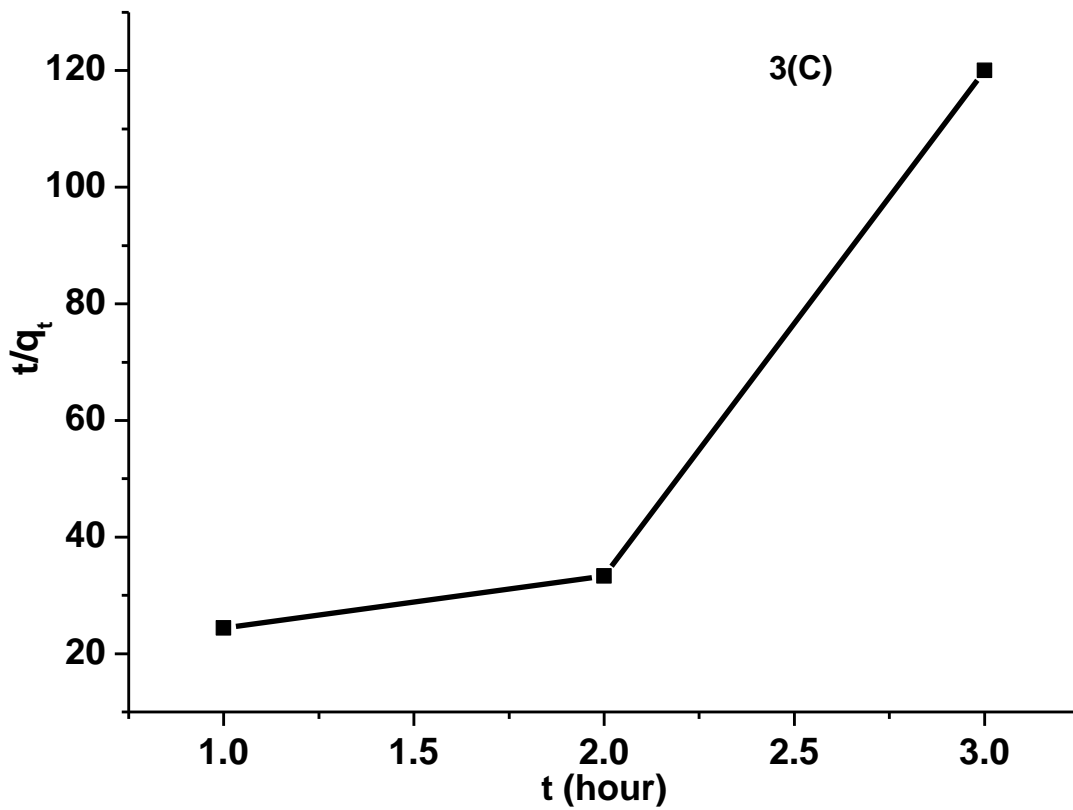


Figure 3(C): Plot of  $t/q_t$  Vs  $t$  with an initial concentration of 4.24 ppm and 1h, 2h and 3h

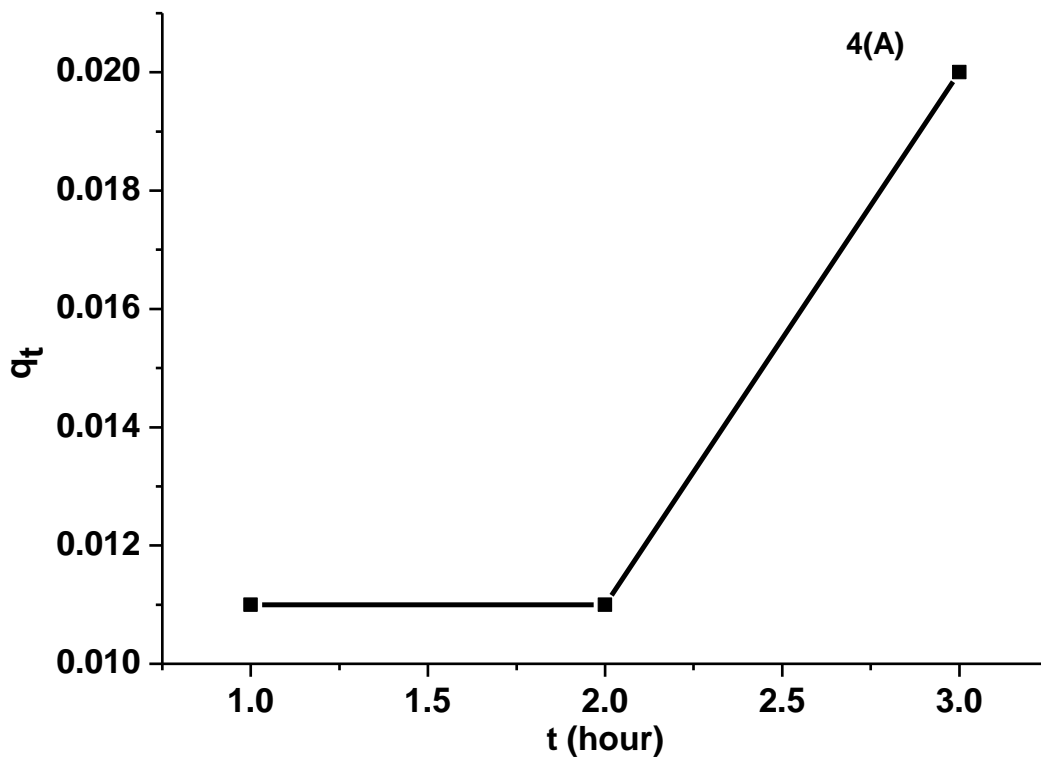


Figure 4(A): Plot of  $q_t$  Vs  $t$  with an initial concentration of 1.44 ppm and 1h, 2h and 3h

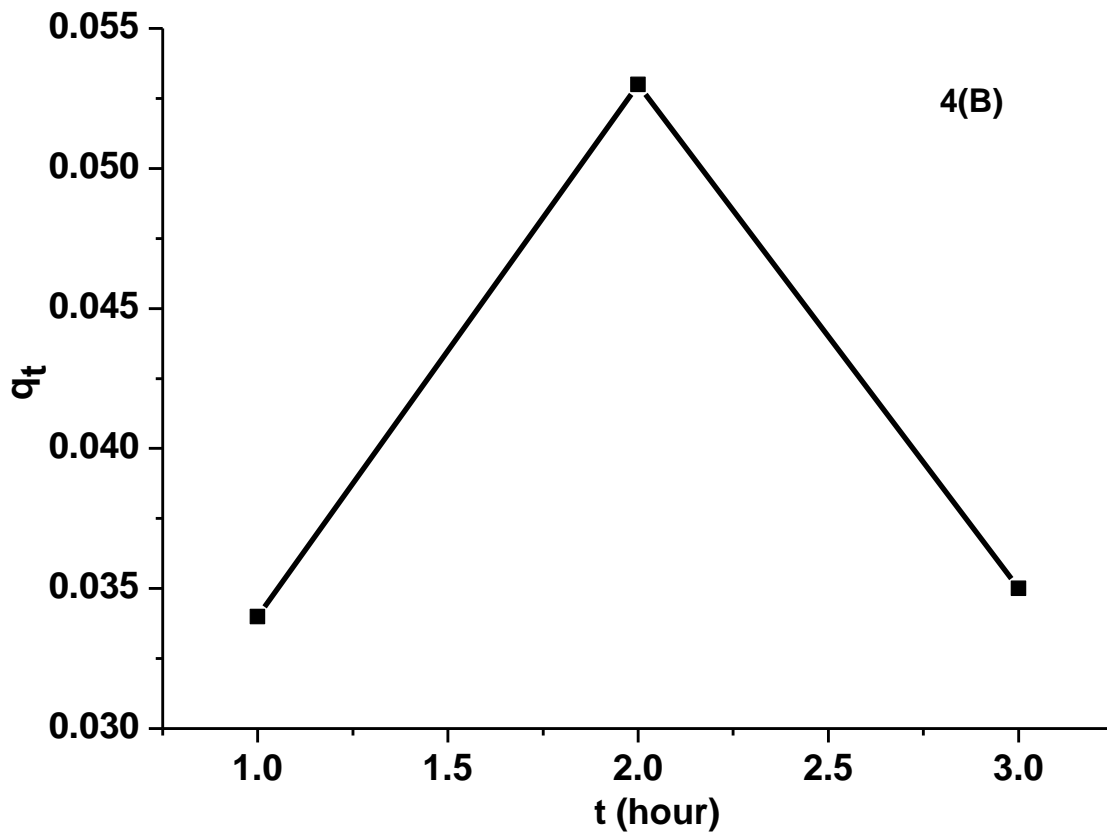


Figure 4(B): Plot of  $q_t$  Vs  $t$  with an initial concentration of 2.99 ppm and 1h, 2h and 3h

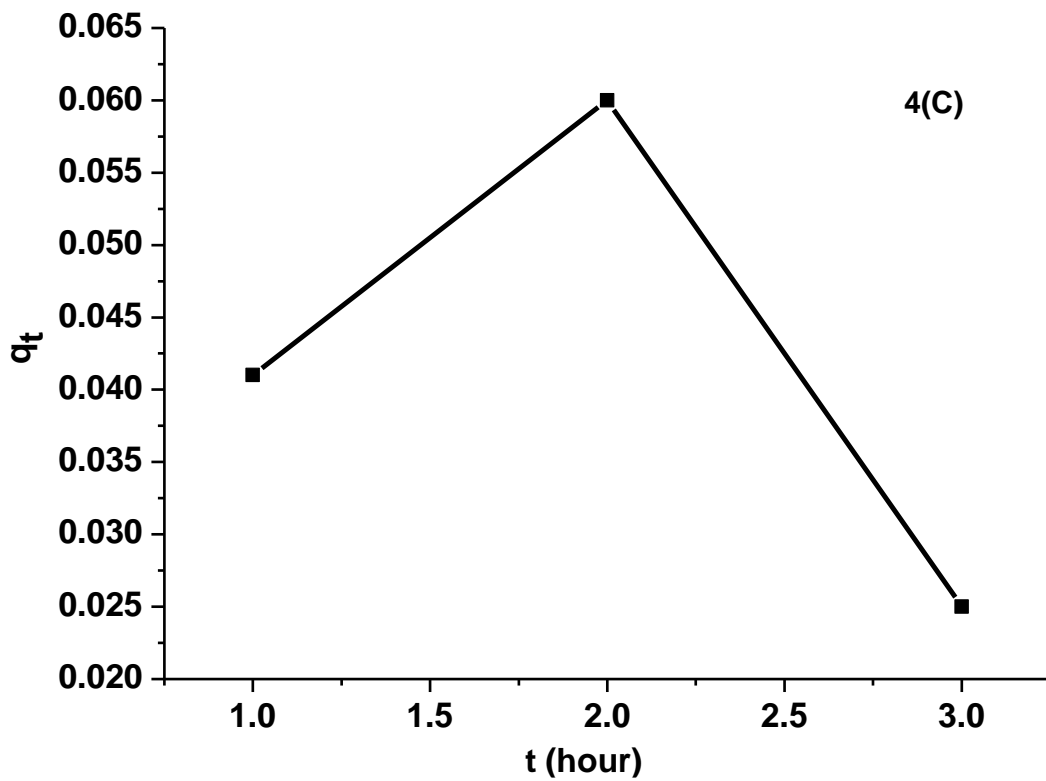


Figure 4(C): Plot of  $q_t$  Vs  $t$  with an initial concentration of 4.24 ppm and 1h, 2h and 3h

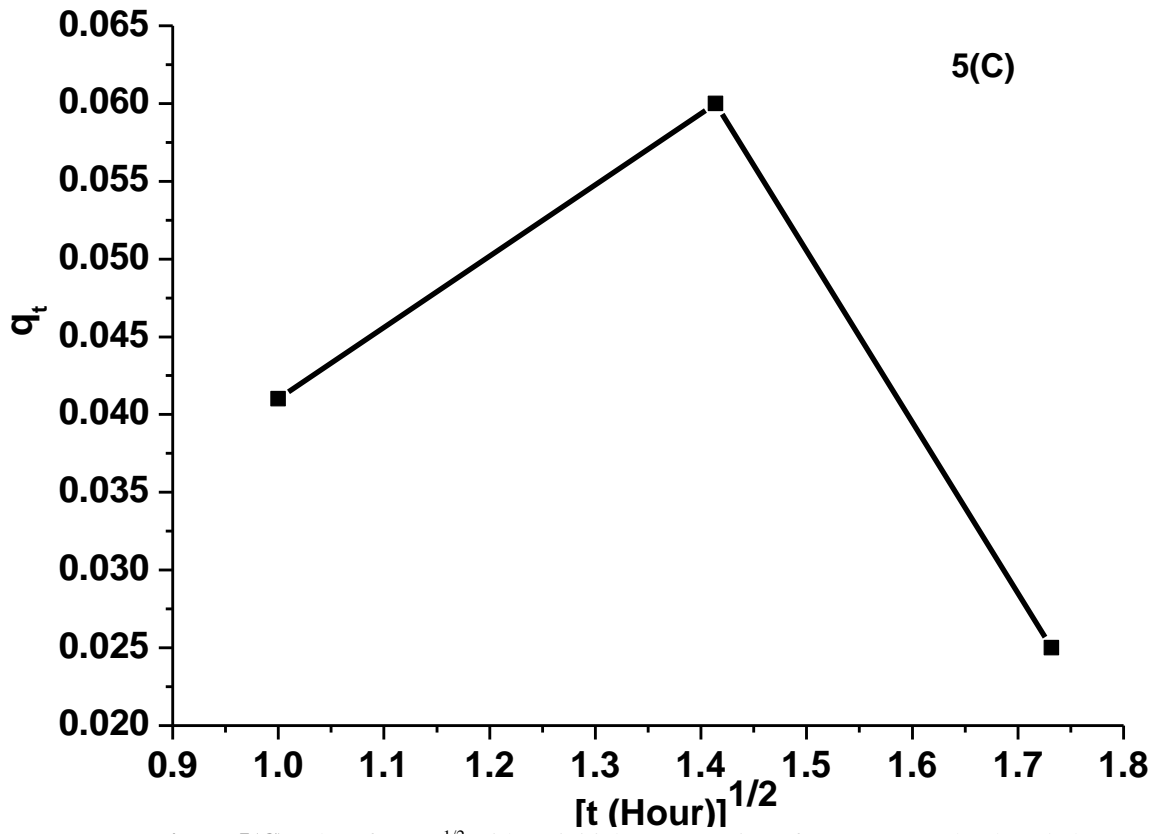


Figure 5(C): Plot of  $q_t$  Vs  $t^{1/2}$  with an initial concentration of 4.24 ppm at 1h, 2h and 3h

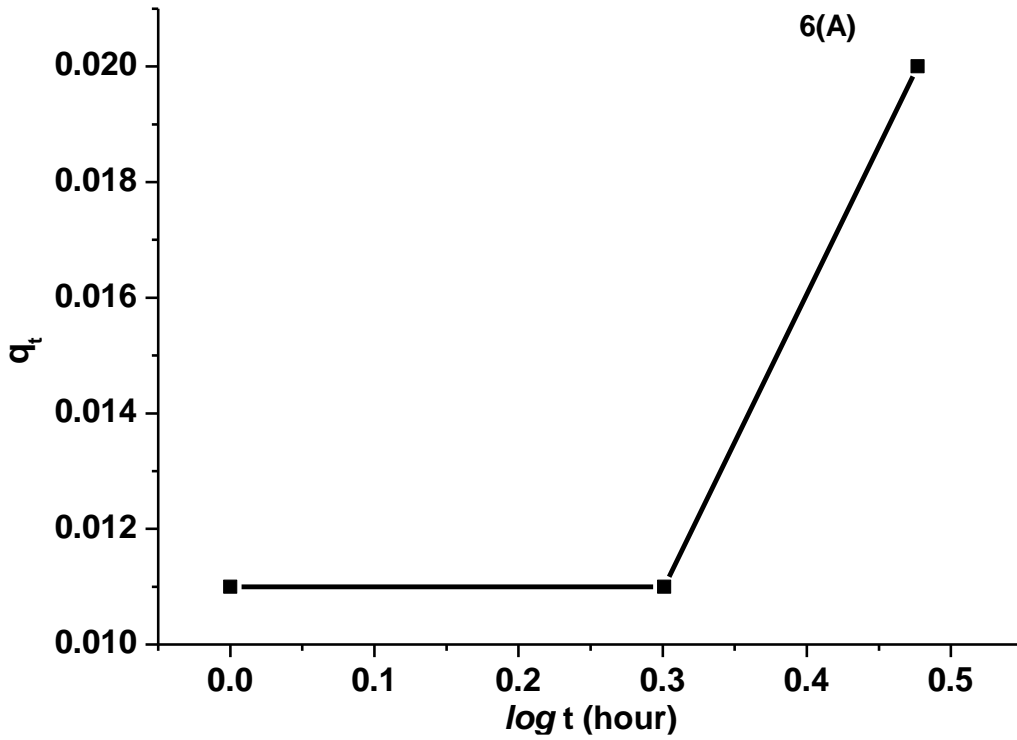


Figure 6(A): Plot of  $q_t$  Vs  $\log t$  with an initial concentration of 1.44 ppm at 1h, 2h and 3h

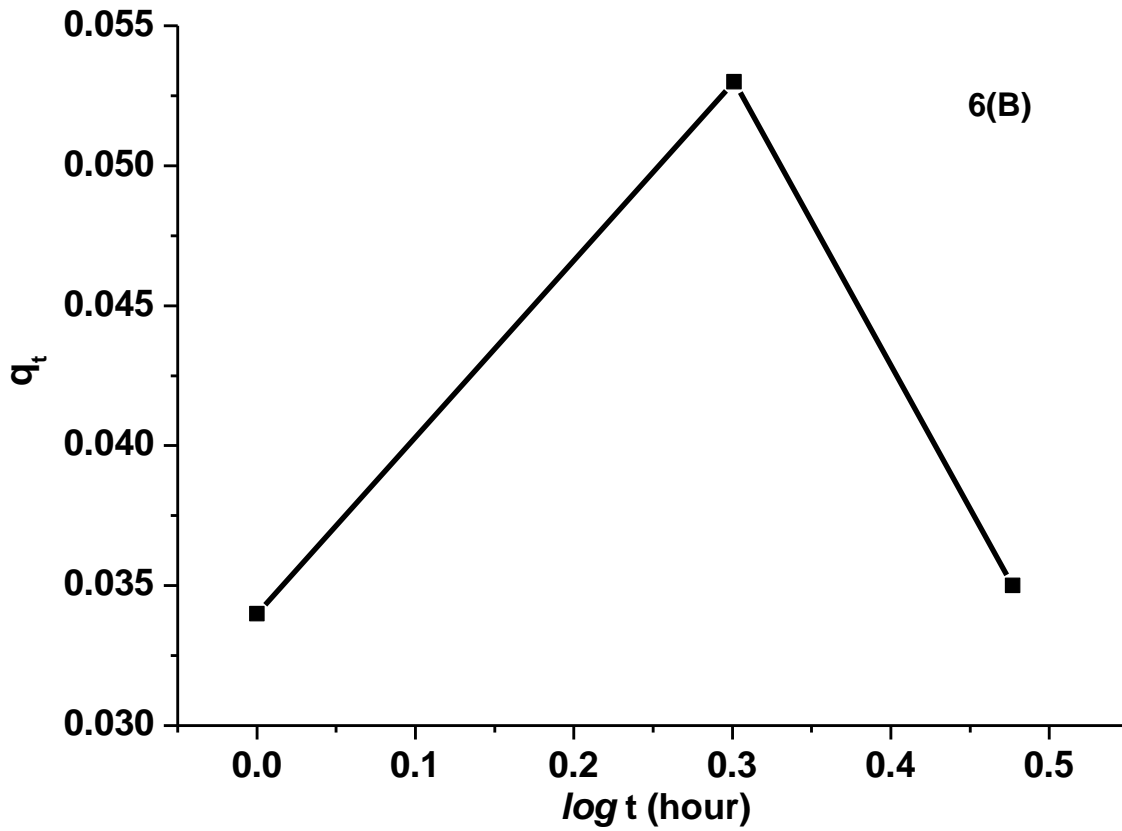


Figure 6(B): Plot of  $q_t$  Vs  $\log t$  with an initial concentration of 2.99 ppm at 1h, 2h and 3h

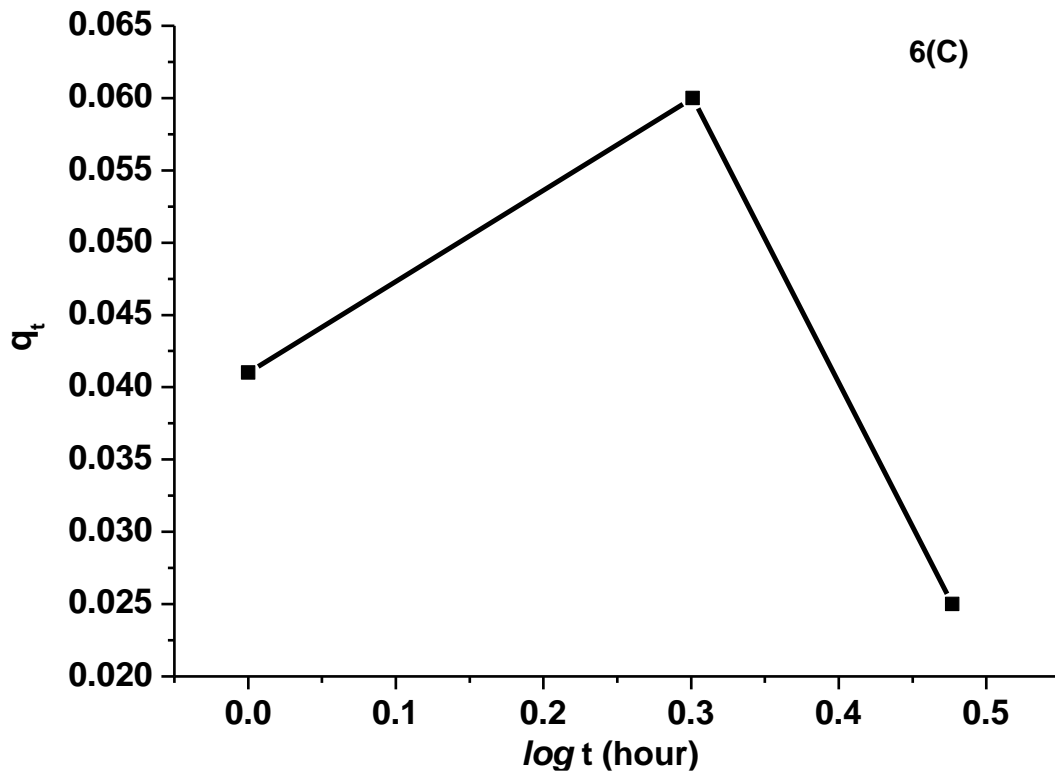


Figure 6(C): Plot of  $q_t$  Vs  $\log t$  with an initial concentration of 4.24 ppm at 1h, 2h and 3h

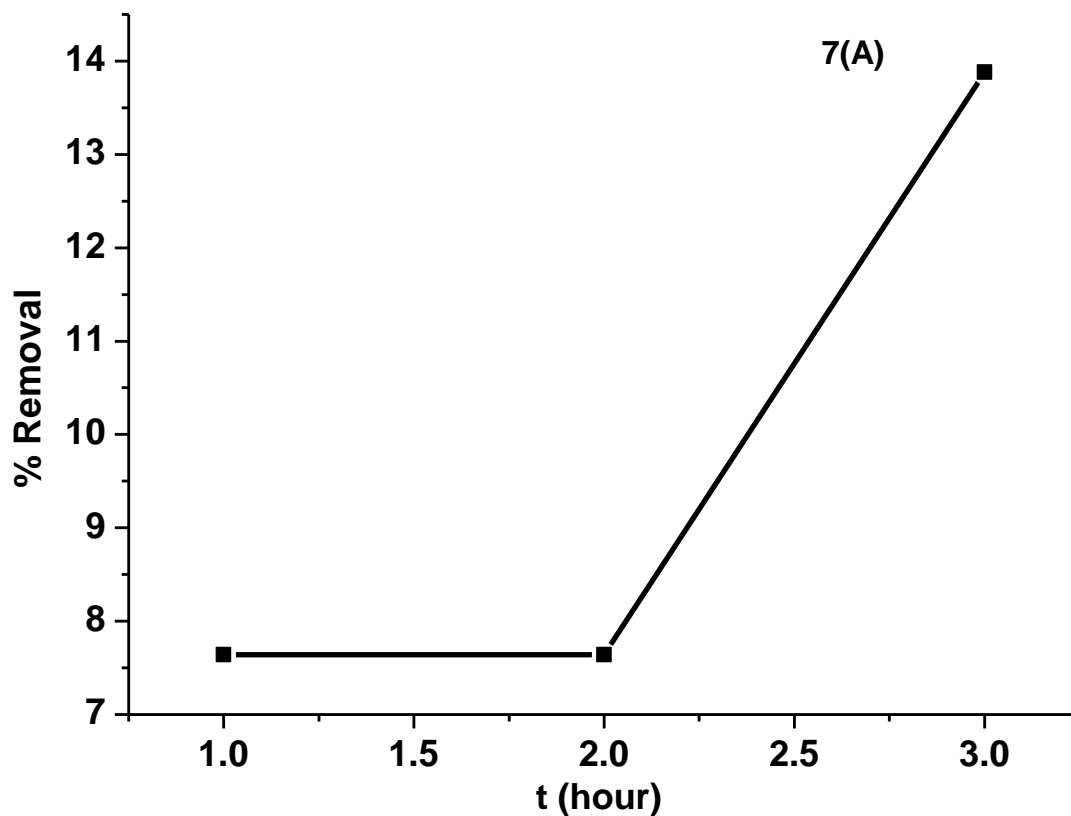


Figure 7(A): Plot of % Removal Vs time with initial concentration 1.44 ppm at 1h, 2h and 3h

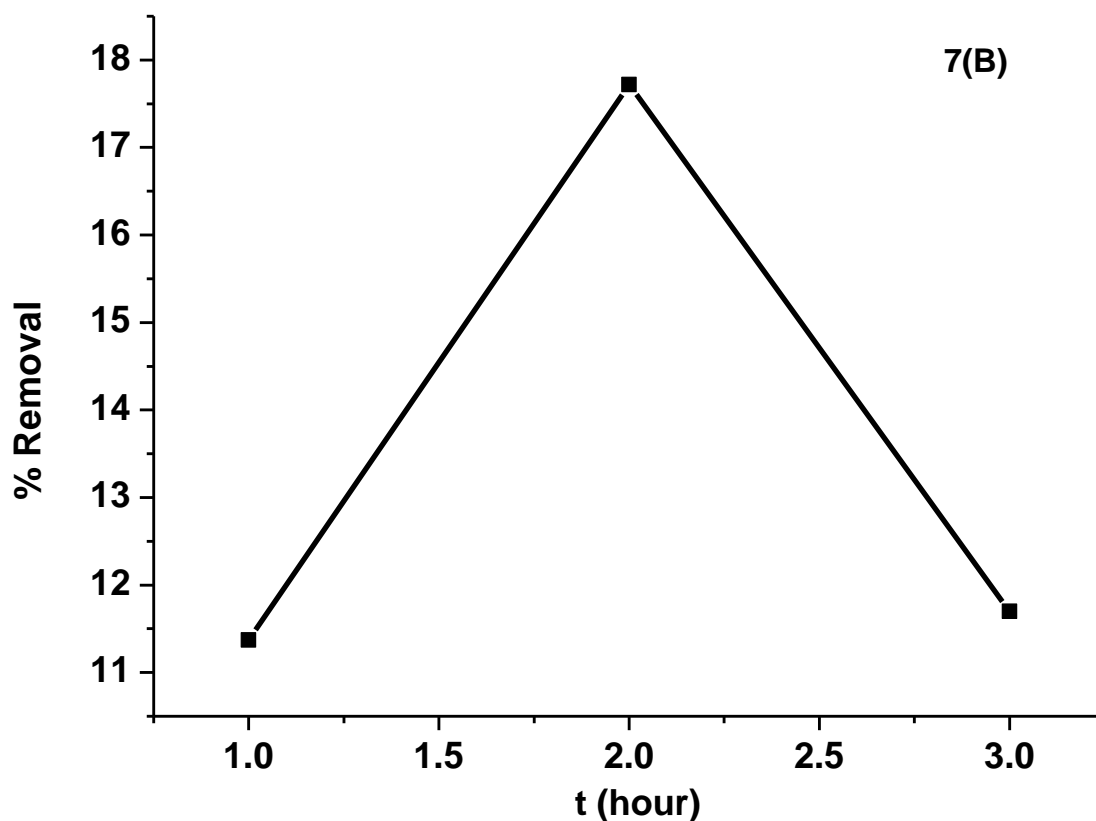


Figure 7(B): Plot of % Removal Vs time with initial concentration 2.99 ppm at 1h, 2h and 3h

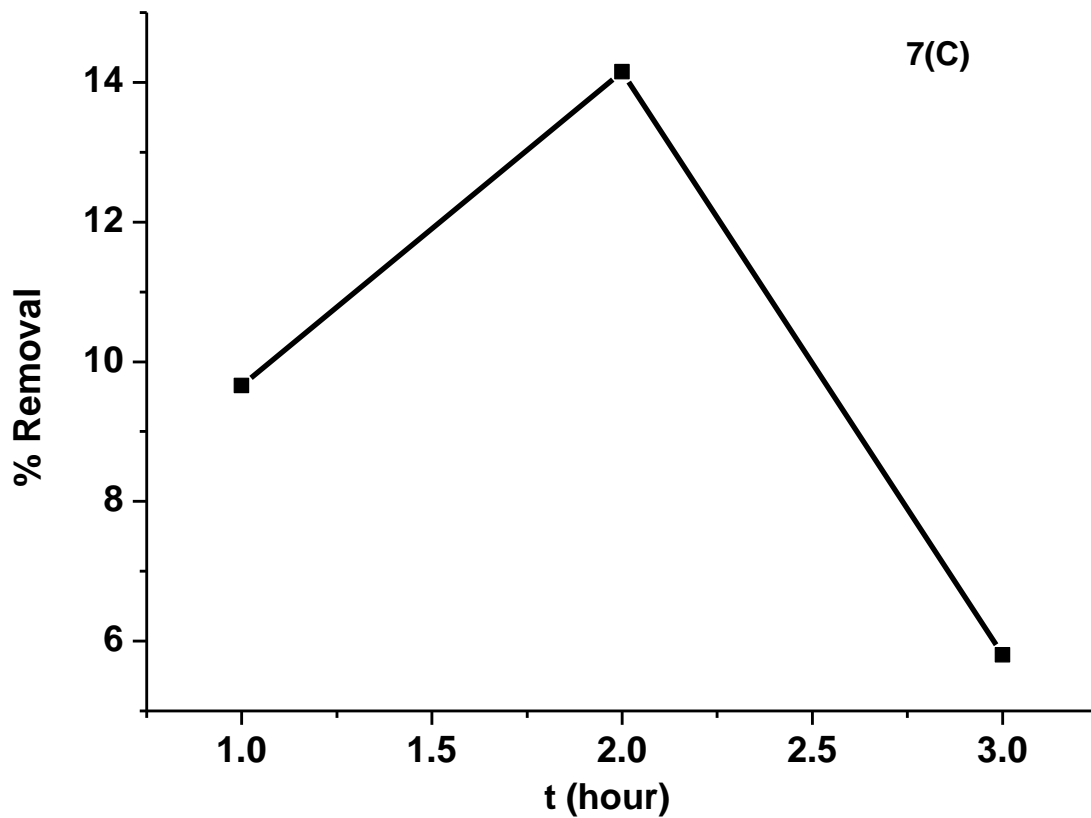


Figure 7(C): Plot of % Removal Vs time with initial concentration 4.24 ppm at 1h, 2h and 3h

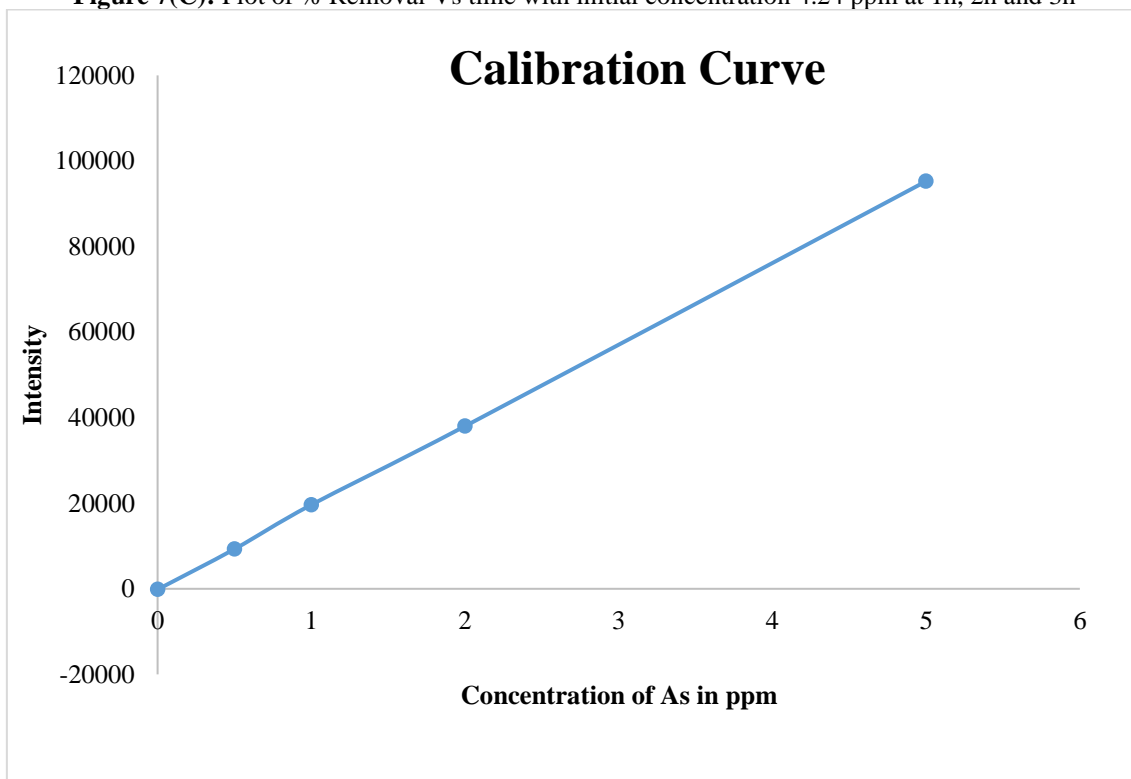


Figure 8: Calibration Curve

**Table 1.** Residual concentration of As(III) in ppm at pH 6.9

| S. N | Weight of biomass | Time | Residual Concentrations in ppm | Initial Concentration in ppm |
|------|-------------------|------|--------------------------------|------------------------------|
| 1    | 1g                | 1h   | 1.33                           | 1.44                         |
| 2    | 2g                | 1h   | 1.28                           | 1.44                         |
| 3    | 3g                | 1h   | 2.54                           | 1.44                         |
| 4    | 4g                | 1h   | 4.13                           | 1.44                         |
| 5    | 1g                | 2h   | 1.33                           | 1.44                         |
| 6    | 1g                | 3h   | 1.24                           | 1.44                         |
| 7    | 1g                | 1h   | 2.65                           | 2.99                         |
| 8    | 2g                | 1h   | 1.43                           | 2.99                         |
| 9    | 3g                | 1h   | 2.62                           | 2.99                         |
| 10   | 4g                | 1h   | 4.02                           | 2.99                         |
| 11   | 1g                | 2h   | 2.46                           | 2.99                         |
| 12   | 1g                | 3h   | 2.64                           | 2.99                         |
| 13   | 1g                | 1h   | 3.83                           | 4.24                         |
| 14   | 2g                | 1h   | 2.4                            | 4.24                         |
| 15   | 3g                | 1h   | 2.5                            | 4.24                         |
| 16   | 4g                | 1h   | 3.63                           | 4.24                         |
| 17   | 1g                | 2h   | 3.64                           | 4.24                         |
| 18   | 1g                | 3h   | 3.99                           | 4.24                         |

**Table 2.** Values of  $q_t$ ,  $\log q_t$ ,  $\log C_t$ ,  $\frac{C_t}{q_t}$  and percentage removal

| S.N | $q_t$ | $C_o$ | $C_t$ | $\log q_t$ | $\log C_t$ | $\frac{C_t}{q_t}$ | % Removal |
|-----|-------|-------|-------|------------|------------|-------------------|-----------|
| 1   | 0.011 | 1.44  | 1.33  | -1.9586    | 0.1235     | 120.9             | 7.64      |
| 2   | 0.008 | 1.44  | 1.28  | -2.0969    | 0.1072     | 160               | 11.11     |
| 3   | 0.011 | 1.44  | 1.33  | -1.9586    | 0.1238     | 120.9             | 7.64      |
| 4   | 0.02  | 1.44  | 1.24  | -1.6989    | 0.093      | 62                | 13.88     |
| 5   | 0.034 | 2.99  | 2.65  | -1.4685    | 0.4232     | 77.94             | 11.37     |
| 6   | 0.078 | 2.99  | 1.43  | -1.1079    | 0.1553     | 18.33             | 52.17     |
| 7   | 0.012 | 2.99  | 2.62  | -1.9208    | 0.4183     | 218.33            | 12.37     |
| 8   | 0.053 | 2.99  | 2.46  | -1.2757    | 0.3909     | 46.41             | 17.72     |
| 9   | 0.035 | 2.99  | 2.64  | -1.4559    | 0.4216     | 75.42             | 11.7      |
| 11  | 0.041 | 4.24  | 3.83  | -1.3872    | 0.5831     | 93.41             | 9.66      |
| 12  | 0.092 | 4.24  | 2.4   | -1.0362    | 0.3802     | 26.08             | 43.39     |
| 13  | 0.058 | 4.24  | 2.5   | -1.2365    | 0.3979     | 43.1              | 41.03     |
| 14  | 0.015 | 4.24  | 3.63  | -1.8234    | 0.5599     | 242               | 14.38     |
| 15  | 0.06  | 4.24  | 3.64  | -1.2218    | 0.5611     | 60.66             | 14.15     |
| 16  | 0.025 | 4.24  | 3.99  | -1.602     | 0.6009     | 159.6             | 5.8       |



#### 4. Conclusions

The experimental data showed the best fit for Freundlich and Langmuir adsorption isotherms. Elovich adsorption isotherm and intraparticle diffusion were not suitable fits for the experimental data. The biomass of *Cymbopogon flexuosus* had been established as a potential adsorbent of arsenic. The essential oil of this plant has medicinal uses in prevention of cancer. This plant should be cultivated on soil free from heavy metal contamination to avoid entry into the body through bio magnifications.

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