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Combating Dioxin and Furan Pollution in Mosul City's Industrial Water Effluents: The Efficacy of ELISA Detection and Tannic Acid Treatment

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ABSTRACT

This study explored the application of enzyme-linked immunosorbent assay (ELISA) and tannic acid treatment for detecting and mitigating dioxin and furan pollution in industrial water effluents of Mosul City. Dioxins and furans, persistent environmental pollutants, pose significant health and ecological risks, especially in urban and industrially active areas such as Mosul. The research emphasized the need for efficient, sensitive, and cost-effective methods to manage these pollutants. ELISA has been identified as a promising method for the detection of dioxins and furans due to its sensitivity, specificity, and lower operational costs compared to traditional chromatographic techniques. This study applied ELISA to assess the concentration of these pollutants in water samples collected from 40 industrial sites across Mosul. The findings revealed substantial initial concentrations of furans and dioxins, which are a concern for both environmental and public health. To address the pollution, the study evaluated the effectiveness of tannic acid, a potential treatment agent, in reducing these contaminants. Samples treated with tannic acid demonstrated significant reductions in the levels of both furans and dioxins, with dioxin concentrations, for example, decreasing from an average of 0.518pg/ml before treatment to 0.041pg/ml after treatment. This notable decline highlighted tannic acid's efficacy in precipitating these harmful compounds from water effluents. The results suggested that ELISA, combined with tannic acid treatment, offered a viable approach for both detecting and reducing dioxin and furan pollution in industrial effluents. This approach could enhance the management of environmental pollutants and contribute to safer water systems in industrial regions. Further research is recommended to optimize treatment processes and validate the long-term applicability of these methods for wider environmental management practices.

INTRODUCTI N

Dioxins and furans are persistent environmental pollutants, recognized for their toxic effects on human health and ecosystems **(Fiedler, 2003; Taylor *et al.*, 2024)**. These compounds, generated predominantly through industrial activities and uncontrolled combustion, are a significant concern for environmental safety and public health, particularly in urban and industrial regions like Mosul City **(Wang *et al.*, 2020; Safavi *et al.*, 2021; Yang *et al.*, 2021)**. The complexities involved in detecting and quantifying

these pollutants in environmental matrices necessitate the development and application of sensitive, reliable, and cost-effective analytical methods **(Kirkok *et al*., 2020)**.

Recent advancements in analytical chemistry have led to the exploration of enzyme-linked immunosorbent assay (ELISA) as a viable technique for the detection of dioxins and furans in various environmental samples **(Jaria *et al.,* 2020)**. The utility of ELISA in environmental monitoring is underscored by its sensitivity, specificity, and relatively low operational costs compared to traditional chromatographic methods **(Alcocj & Jones, 1996; Thiäner *et al.,* 2019)**. Studies by **Xiao *et al.* (2017)** have demonstrated the potential of ELISA in streamlining the identification of dioxin-like compounds through an integrated approach combining bioassay analyses and chemical fractionation, highlighting its applicability in environmental surveillance (CLU-IN).

While detection is a critical aspect of managing dioxin and furan pollution, the removal of these compounds from water systems poses an equally significant challenge. The treatment methodologies for these pollutants require further exploration, particularly in the context of Mosul City's industrial water effluents **(Alcock &Jones, 1996; Prajwal & Murari, 2022)**. This study aimed to bridge this gap by evaluating the efficacy of ELISA in detecting dioxin and furan pollutants and exploring the potential use of tannic acid for their treatment, contributing to the body of knowledge on environmental management and pollution mitigation strategies.

MATERIALS AND METHODS

Sample collection and preparation

Industrial water effluent samples were collected from 40 distinct sites across Mosul City. Samples were retrieved using sterile 2.5L polypropylene bottles, pre-washed with deionized water and ethanol. All samples were stored at 4°C during transportation and were filtered through 0.45µm pore size cellulose acetate filters to remove particulate matter upon arrival at the laboratory. The pH of each sample was measured and adjusted to 7.0± 0.2 using 0.1M HCl or NaOH to optimize conditions for subsequent analysis.

Dioxin and furan concentration determination

The concentrations of dioxin and furan compounds were measured utilizing an enzyme-linked immunosorbent assay (ELISA) kit, procured from MELESA Co **(Fadhel &Albanna, 2020; Yao *et al*., 2021)**. The kit was chosen for its sensitivity and specificity to the target compounds, following manufacturer's protocols. Standard calibration curves were established using known concentrations of dioxin and furan standards provided within the kit. Sample and standards were incubated in pre-coated microtiter plates with anti-dioxin and anti-furan antibodies. Following incubation, samples were washed to remove unbound substances, and a secondary antibody conjugated to a horseradish peroxidase (HRP) enzyme was added. The enzyme-substrate reaction was stopped after a

specific time, and the color change was measured spectrophotometrically at 450nm. The concentration of dioxins and furans in the samples was inferred from the calibration curve.

Tannic acid treatment

Tannic acid, sourced from a commercial supplier, was applied as a treatment agent to a subset of the water samples to assess its efficacy in precipitating dioxin and furan compounds. An initial screening was conducted to determine the optimal dosage of tannic acid, which was then applied to the samples. After treatment, the samples were incubated at room temperature for 24 hours to allow for complex formation, followed by a second round of filtration.

Statistical analysis

Statistical analyses were carried out using SPSS version 25 (IBM Corp.). Descriptive statistics, including means and standard deviations, were computed for all concentration data. A paired-sample t-test was utilized to evaluate the effectiveness of the tannic acid treatment by comparing the concentrations of dioxins and furans before and after treatment. A $P< 0.05$ was considered statistically significant.

Quality control

To ensure the reliability of the results, quality control measures were strictly adhered to throughout the experimental process. This included the use of negative and positive controls in each ELISA plate, periodic calibration of the spectrophotometer, and the implementation of standard operating procedures for sample handling and treatment.

RESULTS AND DISCUSSION

Furan concentrations pre- and post-treatment with tannic acid

The initial phase of the study concentrated on evaluating furan levels at 40 industrial locations within Mosul City. The ELISA kits supplied by MELESA Co. facilitated the establishment of a standard curve for known furan concentrations, enabling accurate blotting of the unknown sample results. The curve was formulated from the absorbance values of standard furan solutions (Fig. 1).

Prior to administering tannic acid, the furan levels were considerably high across the board, with Site 8 registering the highest concentration at 5.75pg/ml. Following treatment, the concentration at Site 8 saw a dramatic decrease to 0.02707pg/ml. The average furan concentration across all sites showed a significant reduction from a pre-treatment level of 1.5pg/ml to a post-treatment level of 0.021pg/ml. This substantial decrease highlights the effectiveness of tannic acid in reducing furan pollution in the industrial effluents of Mosul City (Fig. 2).

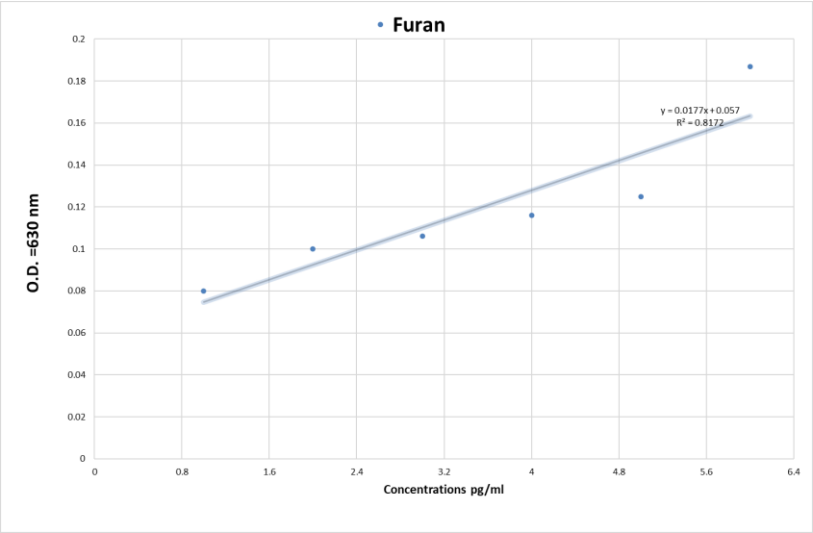

Fig. 1. The standard curve for furan established using known concentrations, resulting in absorbance values that ranged from 0.08 for the 0pg/ml standard to 0.187 for the 6pg/ml standard. This curve is essential for interpolating the furan concentrations of unknown samples based on their measured absorbance.

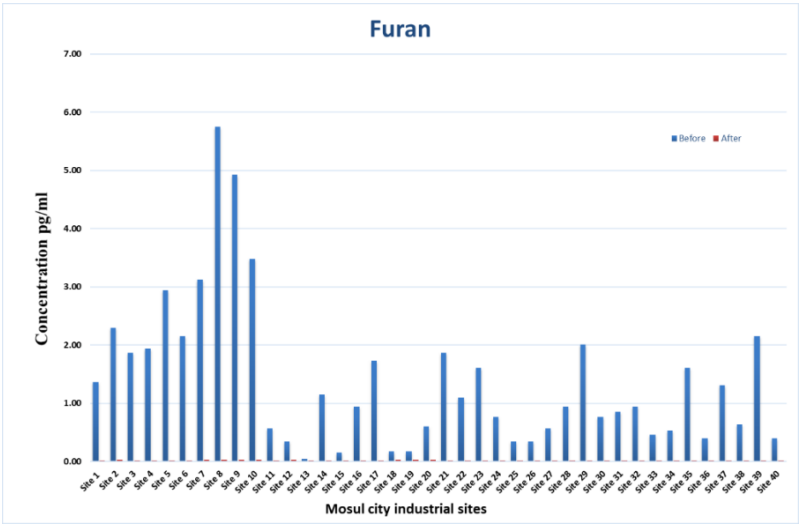

Fig. 2. Histogram showing the determination of furan levels in effluent water samples before and after treatment with tannic acid, indicating a significant decline in furan concentrations post-treatment

Dioxin concentrations pre- and post-treatment with tannic acid

Upon the completion of the furan analysis, attention was shifted to the dioxin concentrations. Employing the ELISA kit, a standard curve for dioxin was developed to blot the unknown samples accurately. This ensured precise quantification of the dioxin levels in the effluents, 0.62323pg/ ml (Fig. 3).

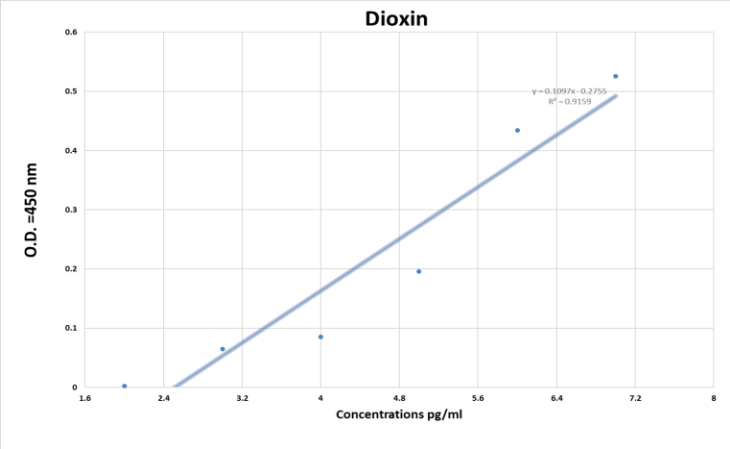

Fig. 3. Standard curve for dioxin, absorbance values ranged from 0.002 at 0pg/ml to 0.526 at 100pg/ml, allowing for the determination of unknown concentrations through this established calibration

After the application of tannic acid, the efficacy of the treatment became evident, with a notable reduction at Site 9 to 0.04098pg/ ml. On average, the dioxin concentrations decreased from 0.51797pg/ml before treatment to 0.041pg/ml after treatment across the surveyed sites. This considerable reduction after treatment with tannic acid demonstrates its potential as an effective remediation agent for dioxin pollutants (Fig. 4).

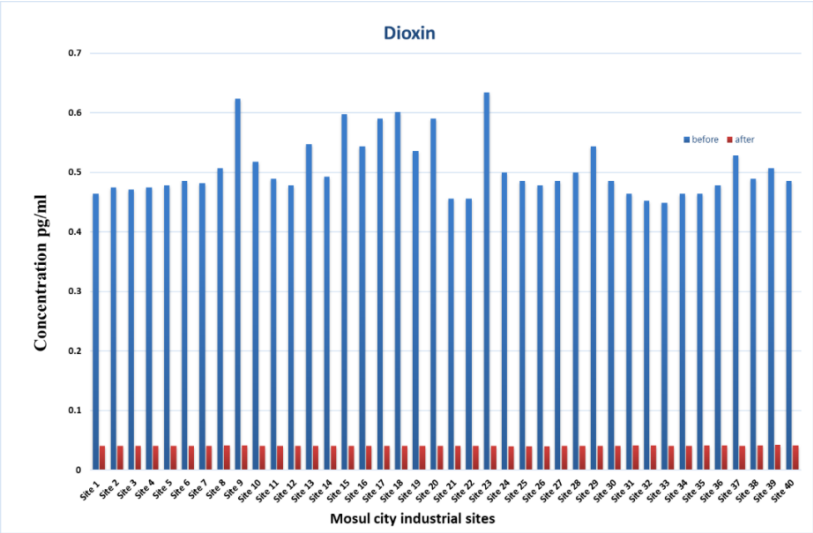

Fig. 4. Histogram showing the determination of dioxin levels in effluent water samples before and after treatment with tannic acid, indicating a significant decline in furan concentrations post-treatment

Overall, the concept of interaction chemical structures of three compounds: Furan and dioxin with tannic acid are represented by a structural diagram showing the

arrangement of atoms and bonds. Furan is a simple aromatic organic compound with a five-membered ring containing oxygen. Tannic acid, depicted with multiple phenolic rings, is a polyphenol with the ability to bind to proteins. Dioxin, indicated in the image by a yellow highlighted structure, is a term commonly used for a family of compounds that are known environmental pollutants, typically associated with industrial processes (Fig. 5).

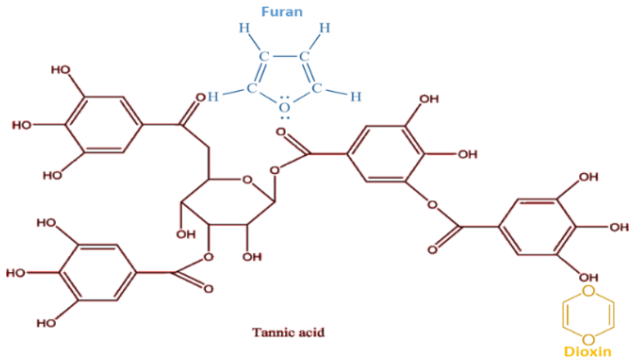

Fig. 5. The diagram displaying the chemical structures interaction compound of furan and dioxin with tannic acid

From a chemical perspective, the interaction between these compounds could involve electron-rich areas (free radical sites) on the furan and dioxin rings undergoing a reaction with the electron-deficient parts of the tannic acid, which is rich in hydroxyl groups. Such interactions could theoretically lead to the formation of adducts or alter the reactivity of furan and dioxin, creating chemical complexes that could facilitate their removal or potentially decrease their toxicity, ultimately aiding in their safe disposal in the environment.

The observed variability in the levels of dioxins and furans across the industrial sites in Mosul City raises significant concerns regarding environmental and public health risks associated with such pollutants. The data indicate a necessity for improved waste management and treatment systems, particularly at sites showing elevated levels of these contaminants **(Abdel-Halim *et al.*, 2003; Yang *et al.*, 2021)**. Furthermore, the comparison between the two sets of data suggests that while certain sites may have efficient control measures in place for one type of pollutant, they may simultaneously exhibit elevated levels of another, pointing toward the need for a comprehensive approach to pollution management. The relatively high concentrations of dioxins and furans necessitate targeted interventions to mitigate their release and curtail their persistence in the aquatic environment **(Arif *et al.*, 2020; Nguyen *et al.*, 2024)**.

The implications of these findings underscore the importance of regular monitoring and the implementation of stricter regulations to ensure industrial compliance

with environmental safety standards. Future work should focus on identifying the sources of highest emissions and developing effective strategies to eliminate or reduce the release of these hazardous compounds.

CONCLUSION

The study conclusively demonstrates that the ELISA method, when paired with tannic acid treatment, provides an effective strategy for detecting and reducing dioxin and furan concentrations in the industrial water effluents of Mosul City. Initial findings revealed high levels of these pollutants across sampled industrial sites, posing serious environmental and health risks. Subsequent application of tannic acid significantly lowered these concentrations, underscoring the potential of this combined approach to improve water quality and enhance public health safety. This research supports the implementation of such innovative methodologies for regular monitoring and treatment of persistent organic pollutants in industrial settings, contributing toward better environmental management and compliance with safety standards. Further investigations and development of these methods could facilitate broader application and optimization for diverse environmental contexts.

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