

Science Research Project Summaries

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Title: *Use of Cryptomelane-Type Manganese Oxide Free Standing Membranes for Removal of Oil Contaminants in Water*

ABSTRACT OF RESEARCH:

The necessity for a material that can absorb oil from the ocean is continuously growing in many areas of the world. Significant oil is spilled into the ocean by careless human activity, such as tanker, barge, pipeline, refinery, and drilling rig accidents. Currently, oil-spill containment booms are used to gather the excess, insoluble oil that floats at the ocean's surface. There remains, however, a need for a practical methodology to remove the unseen, soluble oil that is left behind. This research investigates the synthesis of a free-standing membrane (FSM), that can absorb these soluble hydrocarbons. Precisely, a cryptomelane-type manganese oxide FSM was fabricated, as per methods described by Yuan, et al., with modifications. Scanning electron microscopy, along with ATR-FTIR and EDS spectroscopies, were used to provide evidence for its successful synthesis into a black, absorbent powder. To measure the effectiveness of FMS in remediating soluble oil, gasoline was mixed with water to create 1.7g/L-benzene in water. The fluorescence of benzene-in-water at 250nm/310nm excitation/emission wavelengths was established, and a calibration curve generated based on serial dilutions of 1.7g/L-benzene-in-water. Air-tight measure of FSM's ability to remediate benzene in water was performed. 0.5g of FSM was inserted into 12ml of 1.7g/L-benzene in water, and its 310nm fluorescence measured over 12 hours. Results indicate that 82.3% of benzene was removed, for a 40.8mg-oil/g-FSM absorption rate. Used FSM was inserted into 10ml Ethanol at 30 o C, for recovery of absorbed-oil, and reuse of FSM. 75% recovered was achieved, and the FSM was again ready for use.

Title: *Rapid Detection of Stress Biomarker Cortisol via a Molecularly Imprinted Polypyrrole Sensor*

ABSTRACT OF RESEARCH:

Within 2023, 77% of individuals reported experiencing physical health issues due to stress. Unfortunately, current detection methods for elevated stress are bulky, and require skillful instruments. For these sophisticated tests, cortisol, a common biomarker of stress, is detected. As such, there remains a need for an effective, simple, non-invasive, at-home biosensor for cortisol, so that stress is better managed. This is the goal of the research presented herein. First, a molecularly imprinted polymer (MIP), loaded with cortisol, was fabricated, using ammonium persulfate, pyrrole, and cortisol, while a non-imprinted polymer (NIP) was similarly fabricated, without cortisol, for a comparative control. For the MIP, cortisol was removed, creating cavities for eventual cortisol acceptance and detection, when installed in a biosensor. Ultrasonication instigated ~98% cortisol-loss and cavity creation, which was verified via scanning electron microscopy, ATR-FTIR spectroscopy, and HPLC analysis. Reload of cortisol into receptive cavities of the MIP was carried out using 5mg/ml cortisol solution, which was monitored via HPLC. Analysis of cortisol loss in the MIP-loading solution revealed ~99% of reload of cortisol into the MIP-cavities, based on calculated MIP-cavity capacity. To validate the cortisol-free MIP's electrochemical changes based on cortisol acceptance, MIP current response was measured as a function of purposeful loads of 5-40ng/ml cortisol, and found to be linear. Re-measure of these same solutions for normal (5-30ng/ml) and elevated (+30ng/ml) cortisol via MIP-current response, predicted the stress-marker concentration within ~4% error. The developed MIP-based electroanalytical sensor was found to be effective, cost-friendly, and rapid-response, for futuristic point-of-care diagnostic applications.

Title: *Leveraging of Neural Network Design to Create High-Accuracy, Low-Latency Detection of Deepfake Deception*

ABSTRACT OF RESEARCH:

Deepfakes, an advanced form of AI-driven forgery, enable instant manipulation of video and audio content, posing significant security threats. In February 2024, a multinational corporation lost \$25 million after an employee unknowingly attended a virtual meeting with deepfake impersonations of colleagues, underscoring the urgent need for robust deepfake detection systems. This research develops a video and real-time deepfake detection system using CNNs optimized for high accuracy and low latency. The project began with a video-based detection model utilizing ResNet pre-trained networks, achieving ~92% accuracy after 20 epochs (~20 minutes) on DFDC and Face Forensics datasets. The confusion matrix reported 196 true positives and 168 true negatives, validating the model's effectiveness. To enhance detection across different contexts, two detection pipelines were implemented: a video-based model (92.1% accuracy) for online media and a real-time detection model (81% accuracy) for live-stream scenarios. Techniques such as Fourier Transforms and Local Binary Patterns (LBP) improved accuracy by exposing imperceptible deepfake artifacts. For efficiency, ResNet will be replaced with EfficientNet, minimizing LSTM layers to optimize performance for live-streaming applications. The model's lightweight architecture ensures low computational overhead, making it scalable for deployment on consumer devices and enterprise platforms like Zoom and Microsoft Teams. This efficiency fosters broad adoption and further research, ensuring real-time capabilities to combat digital fraud. This research provides a scalable, cost-effective solution to combat the growing threat of deepfakes across critical industries.