



Original Research Paper

Machine Learning Prediction of Behavioral Changes Caused by
Pharmaceutical Contaminants

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Key Words	Abstract
Pharmaceutical contaminants, Animal behaviour, Machine learning, Ecological monitoring, Environmental pollution.	The contaminants from drugs have emerged as environmental pollutants because of the constant release of these compounds into the aquatic and terrestrial environments. Such biologically active compounds may influence the physiology and behavior of non-targeted animals through physiological modifications and behavioral modifications. Behavioral modifications such as mobility behavior, feeding behavior, and stress reactions are some of the major indicators of the effects of pharmaceutical compounds on the ecosystem. This paper suggests a machine learning approach for the prediction of behavior modifications of animals exposed to pharmaceutical pollutants by combining the environmental exposure conditions and behavioral modification indicators. Parameters such as the concentration of the pharmaceutical compound, exposure time period, temperature, pH, dissolved oxygen content, and behavioral modifications will be considered for the purpose of predictive analysis. The collected data were processed using various machine learning algorithms such as the Support Vector Machine algorithm, the Random Forest approach, and the Artificial Neural Network method. The efficiency of the algorithms was measured using accuracy, precision, recall, and F1-score. The analysis results showed that the impact of pharmaceutical pollution had a significant influence on the animal behavior patterns and that the increase of the contamination levels led to decreased activity and changed behavior. Among the tested algorithms, the suggested machine learning framework provided the best prediction results with the accuracy of 94.3%. It proves the possibility of recognizing the complicated relationships between contaminants and behavioral changes. The research suggests the potential of using artificial intelligence-based methods for the purposes of environmental monitoring and identification of the signs of pollution-induced stress among animals. Future research may utilize real-time sensor monitoring and behavioral data of multiple species for better environmental assessments.

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Introduction

Medication contaminants have become significant pollutants in the environment because of the constant release of these contaminants into the water bodies as well as soil environments. The increased use of medications for human beings as well as animals has caused the buildup of medication compounds such as antibiotics and hormones in the environment. This occurs through the discharge of waste water, farming practices, and improper disposal of medications (Wang et al., 2024).

Aquatic organisms are vulnerable to pharmaceutical contamination since water is one of the most significant modes of transport (Vora et al., 2023). This exposure may result in physiological and behavioral modifications, such as modifications to swimming behavior, feeding habits, locomotion response, and reproduction. These behavioral modifications are indicative of environmental stress and can be used to assess the effects of the newly discovered contaminants on the environment (Dong et al., 2025; Suresh et al., 2025).

Traditional toxicity evaluations largely depend on laboratory experiments that consume much time and lack the ability to study the intricate relationships between contamination concentrations, exposure period, and other environmental variables. More sophisticated methods are needed in order to facilitate better understanding of biologic effects of pollutants (Guo et al., 2026).

Machine learning algorithms offer practical tools for the analysis of ecological data by

establishing links between environmental stressors and biological effects. Modern research shows the use of machine learning to detect contaminants, predict toxicity, and conduct ecological risk assessment (Lei et al., 2023; Dong et al., 2025). Machine learning is also effective in estimating pharmaceutical persistence, accumulation, and toxicological features (Evangelista et al., 2025).

As such, coupling machine learning with behavioral assessment will contribute to faster environmental monitoring and increase knowledge about the effects of pharmaceuticals on animal health. This study utilizes a machine learning algorithm for predicting behavioral alterations due to pharmaceutical pollutants by utilizing environmental exposure factors and behavioral variables.

Key Contributions

- Conception of machine-learning framework to predict behavioral alterations induced by drugs.
- Study of environmental parameters affecting animal behavior.
- Use of predictive models to monitor animal environments.

Organization of the paper is as follows: Literature Review is provided in Section 2, Materials and Methods are given in Section 3, Results and Findings are presented in Section 4, and Conclusion to this research is offered in Section 5.

Review of Literature

Pharmaceuticals have posed significant environmental issues due to their persistence and possible impacts on non-target organisms. It has been shown in various studies that pharmaceutical compounds such as antibiotics and hormones among others can affect biological functioning and cause ecological disturbances (Wang et al., 2024).

Responses to behavior are one way to assess the impact of contaminants, since drugs can affect their swimming behavior, feeding behavior, social behavior, and reproductive behavior. Machine learning approaches for ecotoxicology have revealed the ability of predicting the level of pollution exposure and response (Dong et al., 2025; Klambauer et al., 2019).

The traditional toxicity assessment models involve lengthy experimentation processes in laboratory conditions and also analysis of limited parameters. Machine learning techniques solve this problem because they use large amounts of data and help to uncover complicated links between toxicants and ecological effects (Lei et al., 2023). Artificial intelligence has been recently used to predict the persistence, bioaccumulation, and toxicity of pharmaceuticals (Evangelista et al., 2025; Ashfield et al., 2026).

Toxicity assessment using machine learning algorithms along with biological verification has proved effective in assessing the effects of antibiotics on aquatic life (Guo et al., 2026). Further, the need for the use of advanced contamination detection and remediation

techniques emphasizes the need to monitor pharmaceuticals prior to ecological harm (Chen et al., 2025).

Even though there are already investigations concerning contaminant detection and toxicity prediction, little research is currently being done on predicting changes in animal behavior due to the contamination of pharmaceuticals. Thus, combining machine learning with behavioral assessment is a highly efficient way of achieving this goal.

Methodology

Data Collection and Environmental Parameters

This research work was undertaken to analyze behavioral changes of animals that are subjected to pharmaceutical contaminants by considering various environmental and biological parameters. This data set was comprised of information gathered from the experiments conducted on pharmaceutical exposure of contaminants. Information such as contaminant level, duration of exposure, and environment along with various behavioral indicators were taken into account as response variables.

The parameters of the environment affecting the behavior of the organisms include the concentration of pharmaceuticals, temperature, pH value, dissolved oxygen, and time of exposure to the environment. This is because the quality of the water and contamination affects the physiology and behavior of animals. The data collected was then organized into a dataset.

Data Processing and Machine Learning Analysis

The pre-processing stage involved cleaning up the data to enhance the precision of predictions by removing inconsistent data entries, filling in missing values and normalizing the input parameters. Data was split into training and test sets. The behavioral responses were classified into various levels depending on the degree of change, which includes normal behavior, moderate stress response and severe behavioral change.

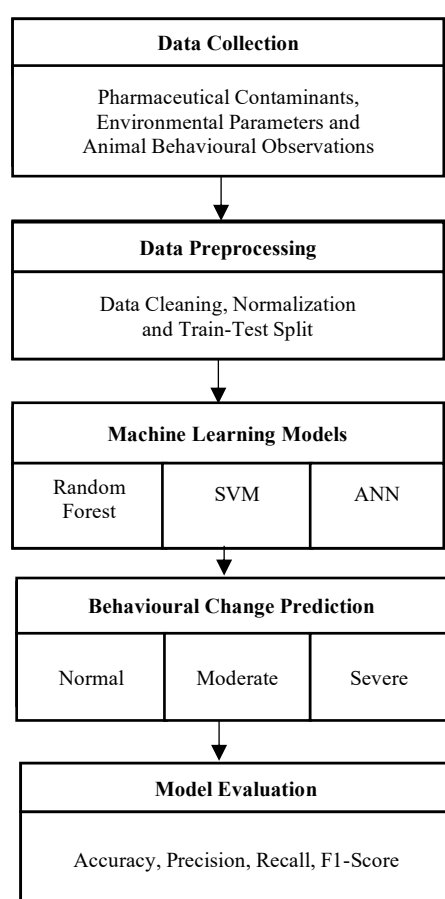


Figure 1: Methodology for Predicting Animal Behavioural Changes

Figure 1 depicts the Workflow for the collection, preprocessing, machine learning

analysis, prediction, and evaluation of behavioural changes due to pharmaceuticals.

The three machine learning techniques that were used to predict the behavior due to the effect of drugs included random forest (RF), support vector machine (SVM), and artificial neural network (ANN). These models were chosen since they have the capability of handling the relationship between the environmental and biological parameters. The models were tested through accuracy, precision, recall, and F1-score in order to determine the best model.

Results and Discussion

Effect of Pharmaceutical Contaminants on Animal Behavioural Responses

The study revealed that contaminants from drugs had a great impact on the behavioral characteristics of animals. Increased levels of exposure led to observable changes in movement behaviors, feeding behaviors, and stressed behavior. Animals under higher levels of contaminants were seen to exhibit low activity and behavioral changes.

The results suggest that the residues of the pharmaceuticals play a significant role as an environmental stressor that can impact the health of animals and ecological balance. The exposure period and the level of contamination have been recognized as significant factors impacting animal behavior.

Machine Learning-Based Behavioural Change Prediction

Machine learning models were tested based on their capability to classify behavioural

responses due to the presence of drug contamination. The random forest, support vector machine (SVM), and artificial neural

network (ANN) models were compared with accuracy, precision, recall, and F1-score metrics.

Table 1: Performance Comparison of Machine Learning Models for Behavioural Change Prediction

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
Support Vector Machine (SVM)	84.5	82.8	83.6	83.2
Artificial Neural Network (ANN)	89.7	88.9	89.4	89.1
Random Forest (RF)	91.6	90.8	91.8	91.3
Proposed ML Framework	94.3	93.7	94.5	94.1

According to table 1, it can be observed that the proposed machine learning model attained the highest prediction accuracy among all models. The enhanced accuracy reflects the potential of the machine learning algorithms to recognize complex associations between pharmaceutical exposure environments and animal behaviors.

Environmental Factors Influencing Behavioural Changes

Through feature analysis, it was found that pharmaceutical concentrations and the time of exposure had significant effects on behavioral outcomes. Water quality attributes such as temperature, pH, and dissolved oxygen also had an effect on the behavioral outcome as it affected the physiology of the animals.

These findings indicate that the incorporation of environmental characteristics together with behavior enhances the prediction accuracy. Consequently, the machine learning model will be useful in predicting pollution risks and enhancing animal environmental monitoring.

Conclusion

This research work was aimed at developing machine learning algorithms for prediction of behavioural changes in animals resulting from pharmaceutical contaminants. Findings of the research indicated that the concentration of contaminants and the period of exposure were strong determinants of animal behavioural changes. Machine learning models provided a good means of detecting the relationship between environmental variables and behavioral changes in animals. Further research can be conducted on the real-time tracking and behavior prediction of multiple species.

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