VER
Vascular & Endovascular Review

Assessing The Role Of Environmental Pollutants And Nutritional Components In Modulating Carcinogenesis in Aquatic Life Using Carcinogenmodnet

Smruti Ranjan Dash, Rashmi Sinha

Assistant Professor, Department of Pharmacy, Kalinga University, Raipur, India.
Assistant Professor, Department of Pharmacy, Kalinga University, Raipur, India.

ABSTRACT

Carcinogenesis in aquatic organisms is an important environmental and ecological issue, arising from exposure to a variety of contaminants and influenced by nutritional factors. This study seeks to evaluate the influence of environmental contaminants and nutritional elements on carcinogenesis in aquatic species using a new computational model, CarcinogenModNet. The model integrates multi-dimensional data on exposure profiles of pollutants, nutritional status, and molecular biomarkers to quantify DNA damage and the risk of cancer in selected aquatic species of interest. CarcinogenModNet predicts the interaction between carcinogenic pollutants (e.g., heavy metals, polycyclic aromatic hydrocarbons, pesticides) and either protective nutritional elements, components that may enhance risk, or promote both. CarcinogenModNet is designed as a prediction model to understand the dynamics of the carcinogenic process associated with exposure to carcinogenic pollutants in various aquatic environments. An important aspect of the study was evaluating the aspects of the nutritional data concerning non-carcinogenic and carcinogenic processes of the aquatic species; thus generalizing the scientific knowledge within CarcinogenModNet as it relates to cancer pathways, DNA damage levels, evaluating the impact of protective nutritional elements, and the potential to mitigate the level of DNA damage. Predictive conclusions from this model also apply to ecological risk assessments and risk to human food safety considerations through the consumption of fish and aquatic organisms. The integrated model is a new advance on traditional toxicological studies and incorporates the environmental and nutritional components of a systems biology approach. The findings highlight the two-fold importance of pollutant exposure and nutritional status or intake in managing carcinogenic risks relevant to aquatic environments. The model can function as a pathway for updates and improvements of CarcinogenModNet using more direct and population-level considerations. Future applications of CarcinogenModNet will focus on expanding species coverage and integrating molecular docking analyses to refine predictive accuracy and support targeted mitigation strategies.

KEYWORDS: Environmental Pollutants, Nutritional Components, Carcinogenesis, Aquatic Life, Computational Modeling, CarcinogenModNet, DNA Damage, Toxicology

How to Cite: Smruti Ranjan Dash, Rashmi Sinha, (2025) Assessing The Role Of Environmental Pollutants And Nutritional Components In Modulating Carcinogenesis in Aquatic Life Using Carcinogenmodnet, Vascular and Endovascular Review, Vol.8, No.1s, 23-26

INTRODUCTION

Carcinogenesis in aquatic species is an important environmental issue impacting biodiversity, ecosystem health, and human populations through the consumption of tainted seafood [2] [10]. Aquatic ecosystems are subjected to a range of increasing environmental pollution, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), and potentially carcinogenic pesticides, which can induce DNA damage and contribute to the development of tumors in aquatic organisms. The carcinogenesis process harms aquatic organisms and our ecosystems, while also threatening food safety.

Nutrition (including macro and micronutrients) is important in cancer and may also provide a protective effect, yet little is known about how nutrients might counteract carcinogenesis. Some nutrients, like antioxidants or essential fatty acids, may lessen the harmful effects of contaminants through better DNA repair and reducing oxidative stress [4]. Nutritional inadequacies and or poor-quality nutrition may increase susceptibility to carcinogens; nutritional balance is key.

The complexity of the influence of pollutants and nutrition on carcinogenesis implies that predictive modelling would be ideally suited to disentangle these multifactor interactions. CarcinogenModNet, a new computational platform, brings important environmental and nutritional information together with molecular biomarker feedback to predict carcinogenesis risk in aquatic organisms [1]. The use of predictive modelling will help to provide a whole-systems perspective on how internal and external factors interact to include cancer development in aquatic animals, with actionable insights for assessment and intervention in risk management [15].

ENVIRONMENTAL POLLUTANTS AND THEIR CARCINOGENIC IMPACT ON AQUATIC LIFE

Aquatic ecosystems are affected by pollutants of varying origin and concentration that can significantly heighten the carcinogenic risk to many aquatic organisms. There are heavy metals like cadmium, mercury, and arsenic that are persistent toxicants and can and do bioaccumulate in tissues as well as parentheses, which activate reactive oxygen species (ROS) that cause oxidative DNA damage [3]. Then, there are polycyclic aromatic hydrocarbons (PAHs), which stem from industrial discharge and oil spills, and create DNA adducts that can interfere with normal cellular machinery and trigger mutagenesis. The well-known pesticides, like organochlorines and organophosphates, are almost universally detected in aquatic habitats and have been demonstrated to be endocrine disruptors and carcinogens in both fish and invertebrates [7].

Table 1: Key Aquatic Pollutants, Mechanistic Pathways of Carcinogenesis, and Species-Level Impacts

Pollutant Type	Common Sources	Carcinogenic Mechanism	Representative Affected Species	Example Molecular Targets
Cadmium (Cd)	Mining runoff, industrial waste	ROS generation, DNA strand breaks	Tilapia, Mussels	p53, DNA repair enzymes
Mercury (Hg)	Industrial discharge, gold mining	Oxidative stress, genotoxicity	Salmon, Clams	Mitochondrial DNA, antioxidant enzymes
Arsenic (As)	Agricultural runoff, groundwater contamination	Chromosomal aberrations, epigenetic changes	Catfish, Shrimp	DNA methyltransferases
PAHs	Oil spills, urban runoff	DNA adduct formation, mutation induction	Flatfish, Oysters	p53, RAS genes
Organochlorine Pesticides	Agricultural discharge	Endocrine disruption, oxidative DNA damage	Carp, Amphibians	Hormone receptors, DNA repair pathways

Table 1 provides a summary of some common environmental pollutants found within aquatic systems, with their likely sources, their carcinogenic modes of action, effects on species, and the molecular pathways within the species affected. These molecular pathways are going to be distinguished in CarcinogenModNet modelling systems as input parameters. The table provides a simple way of considering these pollutants in terms of their ability to cause DNA damage and DNA damage pathways, as well as drawing parallels with previous studies of the emergence of tumours. These summaries will provide an improved understanding of the pollutant-specific risks in studies on aquatic carcinogenesis [5].

The above pollutants produce an altered genetic state and carcinogenesis via multiple mechanisms that each may involve oxidative stress, DNA strand breakage, chromosomal aberrations, and/or acting through DNA repair pathways. Because exposure can be chronic, this can lead to changes in genetic make-up and the formation of tumours that have all been reported in a diversity of different aquatic species, including fish, molluscs, and amphibians, in a variety of environments [6] [14].

Prior studies have provided large quantities of data connecting pollutant-driven carcinogenesis to aquatic life, demonstrating differences in susceptibilities by species as well as distributions of pollutants by spatial patterns of bioaccumulation [9]. CarcinogenModNet combines pollutant data and molecular and ecological factors to illustrate simulated carcinogenicity [12]. By updating the model with pollutant concentration, time of exposure, and species-specific response information, the model produces accurate cancer risk predictions for monitoring environmental factors and spatially managing actions accordingly.

NUTRITIONAL COMPONENTS INFLUENCING CARCINOGENESIS

Nutritional factors strongly modulate carcinogenesis pathways in aquatic species, as they can either enhance or inhibit the impacts of environmental pollutants. Protective nutrients include antioxidants such as vitamins C and E, carotenoids, and selenium, which can mitigate oxidative DNA damage by acting against reactive oxygen species (ROS) generated by toxicants. Anti-inflammatory essential fatty acids, particularly omega-3 polyunsaturated fatty acids, have a role in maintaining cellular homeostasis and inhibiting the growth of tumors.

However, uncertainty regarding nutritional deficiencies or imbalances can make organisms more susceptible to carcinogens. For instance, insufficient antioxidants can also limit the intake of DNA repair mechanisms, while unintentional, excessive exposure to pro-oxidant compounds can impact oxidative stress levels. Similarly, dietary contaminant species, or metabolites of nutrients, can themselves be carcinogens, or co-carcinogens, in aquatic species.

Experimental studies and literature have cited many instances where nutrition modulates the production of carcinogenic outcomes of fish (and some invertebrates). These instances are included in the CarcinogenModNet model, which compiles nutritional profiles in the exposure dataset. The current model structure does capture the concentration and bioavailable amounts of both protective nutrients and risk-enhancing nutrients, providing the capabilities, within a simulation, of gleaning the overall impact on the endpoints of DNA damage and cancer risk [11]. This integrated approach presents a comprehensive interpretation of carcinogenesis in aquatic biosystems and can provide insights into potential risk mitigation based on nutritional strategies [8].

CARCINOGENMODNET MODELING FRAMEWORK AND PREDICTIVE INSIGHTS

CarcinogenModNet represents a new computational modelling tool for use in predicting the carcinogenesis risk (cancer risk) for aquatic organisms by integrating environmental exposure to pollutants and nutrition. We envision our model to have multiple "intakes", including profiles of pollutant concentrations (heavy metals, PAHs, pesticides) and biological levels of nutritional components (antioxidants, vitamins, fatty acids), species susceptibility, and biomarkers indicating DNA damage.

CarcinogenModNet uses machine learning algorithms with systems biology methodology to simulate the dynamics of carcinogens and nutritional modulators and how these components collectively provide influences for the carcinogenic pathways. The model processes probability risk assessment (PRA) based on the DNA mutation and tumour formation as it relates to environmental and dietary conditions, and on duration of exposure.

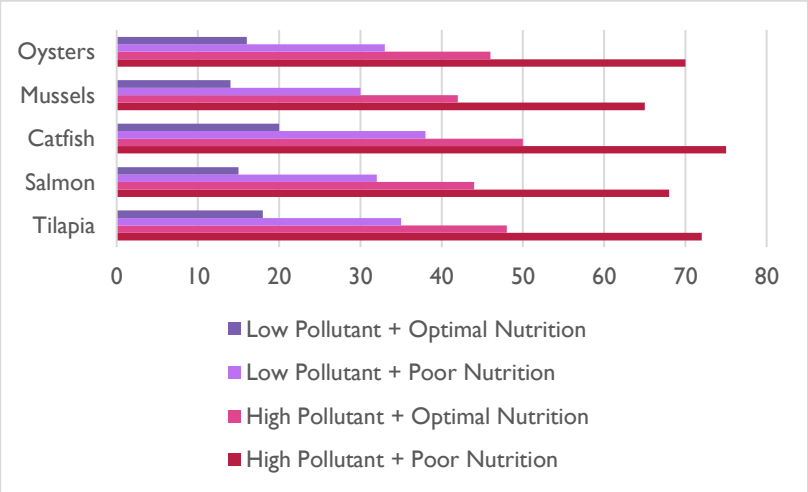

Figure 1: Predicted Carcinogenesis Risk in Selected Aquatic Species Under Combined Pollutant and Nutritional Scenarios (CarcinogenModNet Output)

Figure 1 shows four predicted carcinogenesis risk presentations for various aquatic species under several different environmental situations (high pollutant + poor nutrition, high pollutant + good nutrition, low pollutant + poor nutrition, low pollutant + good nutrition). It directly illustrates that the nutritional aspect can modulate the carcinogenesis risks of environmental pollutants as predicted by CarcinogenModNet, and shows the risk reduction potential of protective nutrients, reinforcing the model's usefulness for environmental management and food safety.

Representation of CarcinogenModNet's Risk Prediction Algorithm:

Let:

- P_i = normalized pollutant exposure index for species i
- N_i normalized nutritional modulation index (positive for protective, negative for risk-enhancing)
- S_i species-specific susceptibility coefficient
- $\beta_0, \beta_1, \beta_2$= model parameters obtained from training data

Risk Probability,

$$R_i = \frac{1}{1 + e^{-(\beta_0 + \beta_1 P_i + \beta_2 N_i + S_i)}}$$

This logistic regression–based risk model can be expanded to include interaction terms $P_i \times N_i$ to reflect the combined effect of pollutants and nutrition. CarcinogenModNet has been validated with experimental datasets and clever use of the literature to develop case studies from exposures within synthetic mixtures of pollutants to fish or mollusc species with known nutritional equivalents. Pilot applications' predictions demonstrated the model's apparent ability to mimic trends corresponding to biological outcomes for carcinogenesis.

The predictive capacity you get with CarcinogenModNet can have significant ecological significance, recognizing early baselines for cancer risk as populations are exposed to radiation and contaminants in their aquatic environment, or for investigations to refine evidence-based management to support or enhance cancer awareness and conservation. The model can also inform human food safety predictions for carcinogen accumulation in edible aquatic species to better comply with regulatory policy in the interest of public health.

CONCLUSION

This study emphasizes the important interaction between environmental contaminants and dietary factors, in terms of the alterations in carcinogenesis in aquatic organisms, using the new CarcinogenModNet modelling framework. The study indicates that dietary factors like antioxidants or essential fatty acids can have a substantial role in the cancer risk and DNA damage with pollutants, and highlights the importance of viewing organisms holistically, considering internal biological factors (dietary) as well as external contaminants (pollution). The CarcinogenModNet model has further highlighted the possibilities for using computational modelling as a tool for risk assessment in aquatic toxicology through the integration of biological and environmental data, which can produce better predictions of carcinogenicity compared to using traditional data sets. Nevertheless, there are some limitations in the current implementation of this model, in terms of data quality (the pollutant and nutritional data available are incomplete), the number of species considered is somewhat limited to only a few species from multiple taxa, and the mechanistic assumptions were necessarily somewhat simplified. Future development of the CarcinogenModNet model could extend its application through expanding the parameters of nutrition and physiology; making use of data obtained from molecular docking simulations study humans and the mechanics at the biomolecular level; expanding upon the number of species and approaches to aquatic organisms in general to increase ecological relevance; and developing the area of multi-scale modelling to gain a greater understanding of effects at the cellular, organismal, and ecosystem levels. Improving the quality of data available and the interpretation of models will improve predictions of the environmental implications of pollutants on aquatic systems. The findings of this study indicate that the CarcinogenModNet modelling framework has considerable potential to benefit preventative practices and approaches to environmental policy focused on reducing carcinogenic risk in aquatic systems, and potentially concerning human health, related to the sustainable use of aquatic food resources.

REFERENCES

1. Younis, A. A., & Alchalabi, A. S. (2025). The Effect of Acidic Environment on Ion Release and Interfacial Adaptation of Two Bioceramic Sealers. Natural and Engineering Sciences, 10(1), 41-55. https://orcid.org/10.28978/nesciences.1611242
2. Chariyev, K., Akchayev, F., Alsalami, Z. A., Santhakumar, B., Musaev, U., & Dewangan, T. (2025). Effect of deep-sea mining on benthic biodiversity and ecosystem services in abyssal zones. International Journal of Aquatic Research and Environmental Studies, 5(1), 204–213. https://doi.org/10.70102/IJARES/V5S1/5-S1-21
3. Kristensen, F., & Einarsson, R. (2022). Bio-Based Polymers: A Sustainable Alternative to Traditional Plastics. International Academic Journal of Innovative Research, 9(3), 13–17. https://doi.org/10.71086/IAJIR/V9I3/IAJIR0920
4. Mehrani, M. J., Tashayoei, M. R., Ferdowsi, A., & Hashemi, H. (2016). Qualitative evaluation of antibiotics in WWTP and review of some antibiotic's removal methods. International Academic Journal of Science and Engineering, 3(1), 174–185.
5. Radhakrishnan, S., Velanganni, R., & Paranthaman, P. (2024). Groundwater Management: Integrating Geological and Hydrological Data for Effective Decision Making. Archives for Technical Sciences, 2(31), 131–139. https://doi.org/10.70102/afts.2024.1631.131
6. Basanta Kumar, R., & Sunil, K. (2024). Biotechnological Approaches to Develop Personalized Medicines for Rare Genetic Disorders. Clinical Journal for Medicine, Health and Pharmacy, 2(2), 20-28.
7. Agarwal, A., & Yadhav, S. (2023). Structure and Functional Guild Composition of Fish Assemblages in the Matla Estuary, Indian Sundarbans. Aquatic Ecosystems and Environmental Frontiers, 1(1), 16-20.
8. Bhardwaj, S., & Ramesh, T. (2024). Advanced Nanofiber Filters for Sterile Filtration in Biopharmaceutical Processes. Engineering Perspectives in Filtration and Separation, 2(2), 5-7.
9. Tamrakar, G. (2025). Optimization of Drag Reduction Using BioInspired Surface Textures in Subsonic Flow. Association Journal of Interdisciplinary Technics in Engineering Mechanics, 3(1), 6-9.
10. Iyer, S., & Verma, R. (2023). Integrating Indigenous Knowledge with GIS for Biodiversity Conservation in Sub-Saharan Africa. International Journal of SDG's Prospects and Breakthroughs, 1(1), 4-7.
11. Verma, A., & Nair, R. (2025). Chromatographic Methods for the Separation of Naturally Occurring Bioactive Compounds and Their Applications in Industry. Engineering Perspectives in Filtration and Separation, 3(1), 18-24.
12. Reddy, N., & Qureshi, I. (2024). Human Reproductive Strategies and Socio-ecological Contexts: An Evolutionary Approach. Progression Journal of Human Demography and Anthropology, 2(2), 5-8.
13. Uzakbaeva, G. B., & Ajiev, A. B. (2022). Legal Regulation of the Use and Protection of Wild Relatives of Cultivated Plants in the Republic of Uzbekistan. International Academic Journal of Social Sciences, 9(1), 43–46. https://doi.org/10.9756/IAJSS/V9I1/IAJSS0905
14. Wei, L., & Johnson, S. (2024). Standardized Terminology for Symptom Reporting in Telemedicine Consultations. Global Journal of Medical Terminology Research and Informatics, 2(2), 14-17.
15. Mehta, A., & Singh, R. K. (2025). Targeting Tumor Microenvironment in Metastatic Cancer. In Medxplore: Frontiers in Medical Science (pp. 1-18). Periodic Series in Multidisciplinary Studies.