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Pesticide Impact on Diatoms in Freshwater Environment

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ABSTRACT

The researchers investigated how pesticides influenced photosynthesis and biomass development in diatoms and other algae. There has been minimal investigation into the effects of these toxic compounds on the internal components of diatom cells. It was discovered that diatoms exposed to harmful substances had nuclear alterations and cell wall abnormalities. However, the specific biological processes that cause these alterations and aberrations remain unknown. Pesticide susceptibility varies greatly across diatom species, as has been thoroughly reported. The capacity of eutrophic and small species to survive pesticide treatment has been extensively established. Smaller species may be less susceptible to oxidative stress owing to better cell defences. However, in general, explaining the reasoning for species-specific tolerance differences has proved difficult thus far. Within this perspective, a crucial topic for future research is understanding diatom intracellular toxicity and the link between these effects and the disturbance of community species composition.

Keywords: Pesticides, Diatoms, intracellular toxicity, cell wall abnormalities

Introduction

A wide variety of harmful pollutants have been released into aquatic environments as a direct consequence of human activities.(IFEN 2006). There has been substantial contamination of streams and groundwater in both agricultural and urban areas, according to an assessment of environmental pesticide residue concentrations in fresh water reservoirs in Telangana. The contamination of streams was relatively concentrated over time, with frequent short pulses of higher pesticide concentrations. Several studies have shown that pesticide levels were higher than 10 µg/L, and in samples taken after severe rainfall, they were even close to 70 µg/L. (Bernardes, et.al., 2015)floods or when rivers are quite high Worries about environmental danger have been heightened by such occurrences.

Estimating the cumulative toxicity of pesticides in stream water is challenging since most ecotoxicity data only exist for individual chemicals. Given the wide variety of harmful compounds (pesticides and their metabolites) that may be present in water sources, the cumulative toxicity of this kind of pollution is much more complicated.(Council, N.R. 2000). Thus, aquatic ecosystems may be seriously endangered due to pesticide contamination, which threatens both their health and production. Pesticides may have devastating effects on bottom-feeding trophic food providers like diatoms, who provide sustenance for countless other creatures. In addition, these contaminants have the potential to greatly disrupt the delicate balance of the food web (Stevenson and Pan 1999).

When other types of algae are unable to grow due to fast water flow, diatoms often step up to the plate as the principal producers (Ghosh and Gaur 1998). Hence, when studying the detrimental impacts of pesticide contamination in aquatic environments, these microalgae are of special relevance. Furthermore, rivers are often polluted by herbicides such as isoproturon, diuron, atrazine, and s-metolachlor because of their extreme toxicity to algae and the widespread use of these pesticides in agriculture and urban areas.(Zhang, et.al., 2011).

Cytology and Cell Ultrastructure Impacts

In diatoms, organelles are highly interconnected. It just takes one change to significantly affect every cellular organelle. How diatoms react to pesticides could be better understood by looking at how various intracellular components react to harmful chemicals. The information on diatoms' intracellular harmful effects is, however, sparse. The effects of pesticide exposure on diatoms' key organelles the intracellular cytoskeleton, nucleus, and cell wall are the primary focus of this study.(Aktar,2009)

Impact on Diatom DNA

The hazardous effects of chemicals on the diatom cellular nucleus have only been the subject of a small number of investigations. In a study conducted by Cassoti et al. (2005), it was shown that the marine diatom Thalassiosira weissflogii experienced DNA dispersion in its cells upon exposure to the aldehyde 2-trans,4-trans-decadienal. Diatom cells treated to maleic hydrazide, a plant growth regulator, exhibited DNA dispersion, as noted by Debenest et al. (2008). It has been observed that the diatom Navicula pelliculosa develops multinuclear cells upon exposure to colchicine. (Duke and Reimann 2012)

Siliceous Cell Wall of Diatoms

The siliceous cell wall, or fuscule, is the most distinctive feature of diatoms. A number of writers have noted that some diatom cells exhibit aberrant shape or disordered ornamentation, which may be caused by xenobiotic exposure. Several harmful substances have been identified as possible causes of defects in the cell wall (frustule) of diatoms. Abnormal frustules were found in samples that were polluted with heavy metals, according to in situ research (Feldt et al. 1973). Diatom communities that were subjected to cadmium, copper, mercury, and zinc also showed abnormal forms (Cattaneo et al. 2004).

Unfortunately, our understanding of the biological processes that give rise to aberrant forms is currently limited. The production of aberrant frustules may be influenced by a lack of silica, according to some writers. Contact with hazardous substances may have distinct intracellular consequences on cells with this impairment. Abnormal frustule induction is thought by several researchers to be connected to an issue with cellular silica absorption Reduced silica absorption might be the result of pollutant-induced membrane change. (Rijstenbil et al. 1994**)** Reduced silica absorption might be the result of pollutant-induced membrane change. (Cattaneo et al. 2004). Oxidative stress caused by radiation or exposure to toxins may potentially be involved in the development of frustule abnormalities (Rijstenbil 2001). Abnormal frustules may be influenced by environmental conditions, such as nutritional deficits and pH (Dickman 1998). Specifically, intense silica deficiencies demonstrate the capacity to cause these anomalies.

Our understanding of the biological processes responsible for the development of aberrant forms is currently limited. Several writers have proposed that a lack of silica is implicated in the production of atypical frustules (Thomas et al. 2020). Such insufficiency may also lead to various intracellular consequences when exposed to harmful substances. Abnormal frustule induction is thought to be associated with a disruption in the absorption of silica by cells, according to several experts.

Impact on Cell Metabolic Rates

Photosynthesis

Herbicides that work by interfering with photosynthesis include s-triazines and substituted ureas (phenylureas and sulphonylureas), which are extensively used in farming. These compounds' active ingredients impede a redox process by binding to a protein known as the D1 protein and blocking electron transfer (Dorigo et al. 2014).

The effects of these compounds on algae have been the subject of a substantial amount of literature. De Noyelles et al. (2002) found that phytoplankton photosynthesis was impacted by atrazine at concentrations ranging from 1 to 5 µg/L. A more noticeable reduction in photosynthesis was seen at doses of 20, 25, and 50 µg/L.It was also found that irrigarol, another s-triazine utilised as an algaecide in antifoulant paints made of copper for maritime boats, inhibits the photosynthetic activity of algae. According to Dahl and Blanck (1996), at low doses (0.063-0.25 µg/L), this algaecide inhibited photosynthesis in subchronic experiments. Other photosynthesis inhibitors, including diquat, hexazinone, and sulfonylureas like chlorsulfuron and metsulfuron, also have effects on diatoms and green algae (Peterson et al. 1997).Periphytic algae subjected to high glyphosate concentrations (8-1800 mg/L) showed a dose-dependent reduction of photosynthesis.

Carbohydrate Synthesis

Phenylurea herbicides like linuron may disrupt carbohydrate synthesis and lead to mobility loss in some diatom species. Microalgae produce polysaccharides that contribute to their motility. Cohn and McGuire (2000) advocated using mobility loss as an indication of hazardous exposure.

Absorption of Nutrients

According to reports, periphytic algae exposed to atrazine exhibited similar behaviour to algae produced under circumstances lacking nutrients (Carder and Hoagland 1998). Atrazine seems to interfere with the cellular uptake of nutrients. However, temperature has a significant impact on this cellular process. Krieger et al. (2008) observed impaired nutrient absorption at a temperature of 10◦C, but not at 25◦C, in several periphytons that were subjected to high levels of four herbicides (alachlor, atrazine, metolachlor, and metribuzin).

The amounts of nitrite and nitrate in the medium also increased when phytoplankton colonies were exposed to simetryn. Herbicides that impede photosynthesis, such as s-triazines, have shown similar effects in other experimental systems.(Peres et al. 1996).

Impacts on the Development of Diatoms

The quantities of chlorophyll pigments are examined in order to determine the biomass of algae. This may be done via the use of either traditional spectrophotometry or liquid chromatography. Among the several metrics used to evaluate pesticide impacts on algal development, chlorophyll a measurement stands out. Multiple authors have shown that diatoms and other algae may reduce their chlorophyll a content when exposed to atrazine doses ranging from 10 to 1000 μg/L(Damalas, 2011).

Impacts on the Diversity of Species

When some species are exposed to pesticides, either alone or in combination, it may disrupt the community's delicate equilibrium. Atrazine and other toxic compounds may slow the growth of certain species in an ecosystem, even if the impacts are hard to see. This might benefit the more resilient species (Berard and Pelte 1996).

Disruptions to the Diatom Response to Pesticide Exposure

When diatoms come into touch with pesticides, it might disrupt a lot of ecological and environmental factors. Because the intricate biological matrix (biofilm) where benthic diatoms evolve may shield these algae from the effects of pesticides, it can be difficult to definitively link ecological disturbances seen in a population to pesticide exposure under natural conditions (Peres et al. 1996).

Toxic agent exposures, including atrazine, affect benthic diatom populations in ways that are dependent on colonisation dynamics and biofilm development. Invertebrate or fish grazers may disrupt this protective covering, alter cell structure, and enhance harmful effects. Still, it's still not easy to tell how these grazers affect diatoms' reactions to hazardous exposure. Planktonic diatoms have adapted to a poisonous environment via deep-diving, even though they lack protective coatings (Rijstenbil 2001). Particularly in agricultural watersheds, where nitrate pollution is prevalent, the spatiotemporal changes in nutrient concentrations must impede the ability of algae to respond to hazardous chemicals in field circumstances.

Summary and Recommendations

Researchers looked at how pesticides affected photosynthesis and biomass growth in diatoms and other algae. The impact of these harmful substances on the intracellular components of diatom cells has been the subject of little research. It was shown that diatoms exposed to hazardous chemicals had nuclear changes and cell wall defects. However, the exact biological pathways that lead to these changes and anomalies are still not well understood. It is well-documented that various diatom species exhibit vastly varied pesticide sensitivity. The ability of eutrophic and tiny species to withstand exposure to pesticides is well-documented. It is possible that smaller species' lack of susceptibility is due to their stronger cell defences against oxidative stress. However, generally speaking, it has proven fairly challenging to explain the logic underlying species-specific tolerance variances thus far. Within this framework, an important area for future study is the comprehension of diatom intracellular toxicity and the connection between these effects and the disruption of community species composition.

When exposed to hazardous agents, diatom communities react differently depending on the initial species composition of the community. Communities of diatoms may persist in the face of intense pesticide contamination if they include species that can transition from autotrophic to heterotrophic modes in response to photosynthesis inhibition, such as occurs after exposure to certain pesticides. Cell and community health, ecological relationships with other creatures, and general environmental circumstances all have a role in how and to what extent diatoms react to toxic stress. Diatom communities' overall structural characteristics, such as biomass and global cell density, are more resilient to pesticide impacts than the particular structural parameters of the organisms, which include species-specific cell density and species composition. Biofilm formation and the subsequent feeding of invertebrates and fishes on this matrix may alter diatom communities' reactions for benthic species. The way diatoms react to pesticides is affected by and often obstructed by environmental factors like as light intensity, nutrient concentrations, and hydraulic conditions. Consequently, researchers are unable to readily discern the impacts of pesticide contamination on diatoms due to the intricate nature of both aquatic ecosystems and the various molecules interacting in stream water. To solve this issue, obviously, further study is needed.

Compliance with ethical standards:

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Disclosure of conflict of interest

The authors (Dr Raju Potharaju, Prof M. Aruna) declare no conflict of interest.

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