



ENVIRONMENTAL EXPOSURES AND TYPE 2 DIABETES: EVIDENCE, BIOLOGICAL MECHANISMS AND RESEARCH PRIORITIES

¹Dr. Puberun Jyoti Boruah, ^{2*}Mridu Manjil Bhuyan

¹Assam Medical College and Hospital, Barbari, Dibrugarh, 786002, Assam, India.

²The Assam Royal Global University, Betkuchi, Guwahati, 781035, Assam, India.



***Corresponding Author: Mridu Manjil Bhuyan**

The Assam Royal Global University, Betkuchi, Guwahati, 781035, Assam, India.

DOI: <https://doi.org/10.5281/zenodo.23805301>



How to cite this Article: ¹Dr. Puberun Jyoti Boruah, ^{2*}Mridu Manjil Bhuyan (2026). Environmental Exposures And Type 2 Diabetes: Evidence, Biological Mechanisms And Research Priorities. World Journal of Pharmaceutical and Life Sciences, 12(11), 109–112.

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Article Received on 05/10/2026

Article Revised on 25/10/2026

Article Published on 01/11/2026

ABSTRACT

Type 2 diabetes (T2D) is influenced not only by genetic, behavioural and clinical factors but also by broader environmental conditions. This study looks at how things like air pollution, farm chemicals, toxic pollutants, heavy metals and climate change impact the risk of getting Type 2 Diabetes. The reviewed literature suggests possible associations between T2D and air pollution, agricultural or occupational exposures, environmental factors but findings vary by exposure and human population. Evidence presented that several exposures may contribute to insulin resistance, beta-cell dysfunction, oxidative stress, chronic inflammation and altered metabolic regulation. However, it's hard to understand the effects of these ecological factors because they can be complex and varied. The study suggests that these external substances can disrupt the body's metabolic systems. To make progress, future research needs to focus on diverse groups of people, use standardized measures of exposure and track interventions consistently to improve prevention and treatment outcomes.

KEYWORDS: Environmental Exposure, Air Pollution, Type 2 diabetes, Ecological Contaminant.

1. INTRODUCTION

The way people get type 2 diabetes is complex and involves how well the body uses insulin and how well the pancreas works.^[23] But it's not just about the individual; but where we live, work and play also plays a big role. Things like our jobs, homes, transportation, food, pollution and even the climate can all contribute to the risk of getting type 2 diabetes.^{[4][9][10]} That's why researchers look at the bigger picture, including social and environmental factors. When trying to understand how to prevent and treat this disease. They've found that by considering all these factors together, can better understand how to address the problem. For example, studies have shown that access to healthy food, safe housing and clean air can all make a difference in reducing the risk of type 2 diabetes. By looking at the whole picture, can work towards creating healthier communities and reducing the burden of this disease.

This review asks whether environmental exposure can alter antidiabetic treatment response. Just because something is linked to diabetes or makes blood sugar levels worse, it doesn't mean it will affect. Heat exposure may disrupt self-management behaviours, hydration, physical activity and access to care. Some things can make your body less responsive to insulin and it can be hard to get the treatment you need. This is important to keep in mind when thinking about how different factors can impact health and treatment plan.

2. METHODOLOGY

This review focused on how environmental exposures may contribute to type 2 diabetes. How affect nutrient metabolism and alter responses to T2D. On October 16, 2026, we searched PubMed, Google Scholar, Scopus and Web of Science without restricting publication year. The articles considered spanned 2009 to the search date. Search concepts included the Environmental Exposure, Air Pollution, Type 2 diabetes and Ecological

Contaminant. We recorded the main concepts but not the exact search terms or the number of results. We also followed references in other reviews and checked key details against original sources, including PubMed and publisher records. We excluded studies that did not address environmental effects on diabetes or nutrient metabolism. The original manuscript cited 20 references and five were added during revision. The final bibliography is reported to contain 25 cited references. We did not record search, screening or exclusion counts, duplicate records or independent reviewer procedures. The final bibliography was checked manually by title and DOI.

3. Environmental Exposures and Type 2 Diabetes Susceptibility

3.1 Ambient Pollution and urban environment

Research has shown that there is a link between type 2 diabetes and air pollution, but it's not a strong one. Studies have found that tiny particles, nitrogen di-oxide and ozone in the air can contribute to the disease. But the results vary depending on the type of pollution and the population being studied.^{[7][16]} Some models have tried to identify patterns of exposure to multiple pollutants, but they don't necessarily show what's causing the disease.^{[15][18]} A study called the KORA cohort looked at how air pollution, noise from traffic, green spaces and temperature affected the risk of developing type 2 diabetes but they didn't find much of a connection.^[2] Overall, the evidence suggests that need to keep studying how environmental factors affect the population as a whole, rather than trying to pinpoint individual risks.

3.2 Agricultural and Occupational exposures

Agricultural work may involve multiple health-relevant exposures, including pesticides, organic dust, heat stress and physically demanding labour. It's not just the hard physical work, but also the chemicals, dust and heat that come with farming. Some studies have looked at how farming might be linked to diabetes. Researchers in Saskatchewan and some villages in South India found some connections between farm work and diabetes. They also found that pesticides might play a role. But it's hard to say for sure because different studies have used different methods and definitions.^{[6][20][21]} All this information can help us keep an eye on farm workers' health and try to prevent problems, but it's still not clear what exactly is causing these health issues or how it affects how people.^[4]

3.3 Chemicals, Persistent pollutants and Metals

Humans are exposed to a wide range of harmful substances, including endocrine-disrupting chemicals, pollutants and metals. These substances can affect our bodies in different ways, depending on the dose and how long they stick around. possible effects on insulin signalling, adipose biology, islets and beta cells but findings vary by agents and models.^{[16][3][8][25]} However, it's not always clear how these findings apply to humans. Some occupational cohort and prospective PFAS studies

of people who work with these substances have found possible links to health problems, but the evidence isn't consistent across all substances.^{[5][11]} A recent analysis of environmental toxins found some potential culprits. But more research is needed to confirm these findings. The problem is that these substances often occur in mixtures and their effects can be unpredictable. Which making it difficult to pinpoint a single cause or estimate the overall impact.^[24]

3.4 Water, climate and humidity

Research on groundwater contamination has yielded mixed results. That making it difficult to draw concrete conclusions due to varying geographical and social factors.^[16] For instance, a study in Finland found no significant difference in gestational or subsequent T2D after a brief early-pregnancy faecal contamination event. However, this study does not account for the effects of chronic chemical contamination.^[12] Climate change is also a concern, as it can lead to increased heat exposure, poor air quality, food insecurity and disruptions in healthcare services.^[19] Some studies have suggested a link between high humidity and elevated blood sugar as well as changes in the gut's barrier function, but more research is needed to confirm these findings.^[22]

4. Candidate biological pathways

Researchers think that several pathways lead to problems like insulin resistance, issues with beta cells, inflammation, oxidative stress and how the body handles energy. One study found that exposure to a type of air pollution called PM2.5 can cause insulin resistance and inflammation in the body.^[14] Other researchers have looked at how certain chemicals called EDCs, might affect how insulin is released, the way hormones send signals, mitochondria's work and how beta cells survive.^{[8][25]} However, these studies were done in controlled environments. So, they might not accurately represent what happens in real-life situations, where people are exposed to many different substances at varying levels and for different amounts of time.

5. Research Priorities

The groups of people for study should be diverse, including different jobs, climates, income levels, social structure and healthcare systems. Research should only use information about the environment to guide how T2D may appear from environmental effects and it can lead to a meaningful outcome and improve the benefits or safety of the treatment. This means need to see that the interaction between humans and the environment is consistent and that our interventions are actually making a difference.

6. DISCUSSION

This review indicates that environmental exposures may contribute to T2D susceptibility. Although the evidence remains heterogeneous but largely associative. Air pollutants (PM2.5, NO2, ozone) show inconsistent links to incident T2D across populations and the KORA cohort

found little association with pollution, noise, greenness or temperature. Agricultural and occupational studies suggest elevated risk of possibility via pesticides, but definitional and methodological differences limit comparability. Evidence for endocrine-disrupting chemicals, PFAS and metals is similarly inconsistent and mixture effects complicate causal attribution. Mechanistic data implicate insulin resistance, β -cell dysfunction, oxidative stress and inflammation. Yet derive mainly from experimental models whose exposure conditions poorly reflect real-world with multi-agent exposure. Future studies should employ standardized exposure metrics, diverse populations and longitudinal designs. Which integrating treatment outcomes to enable exposure-informed prevention and therapy.

7. CONCLUSION

The Type 2 Diabetes (T2D) pathogenesis is inextricably linked to complex socio-environmental determinants beyond individual factors. Diabetes is a complex health issue that is affected by more than just individual factors. Things like air pollution, farm, chemicals and climate change can all play a role in making people more likely to get Type 2 Diabetes. These environmental stressors can cause problems in the body. Like making it harder to use insulin, increasing inflammation and damaging the cells in the pancreas that produce insulin. But it is hard to study the effects of these stressors because they can be different everywhere and can interact with each other in complicated ways. To make progress in understanding and treating Type 2 Diabetes, we need to do more research that includes people from different backgrounds and living in different environments. Research can develop more effective strategies to reduce the global impact of Type 2 Diabetes. This could involve looking at how diet, lifestyle and environmental factors interact to increase diabetes risk. Ultimately, integrating ecological perspectives into diabetes research will enable more precise interventions; enhanced treatment safety and targeted strategies to reduce the global burden of Type 2 Diabetes.

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