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Environmental Factors in Causation of Diabetes Mellitus

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<http://dx.doi.org/10.5772/62543>

Abstract

Environmental factors play a role in etiopathogenesis of diabetes. Environmental factors include polluted water, soil, unhealthy diet, stress, lack of physical activity, vitamin D deficiency, exposure to enteroviruses, and damage to immune cells.

Keywords: diabetes, virus, diet, stress, pollutants, prenatal factors, cow's milk, vitamin D deficiency

1. Introduction

India is currently experiencing an epidemic of diabetes mellitus (DM). According to the World Health Organization, India has the unique distinction of being the country with the largest number of diabetic patients in the world. Type-2 DM accounts for more than 90% of all patients with diabetes worldwide. The prevalence of diabetes in adults is showing an upward trend worldwide [4% in 1995 to 5.4% in 2025 (projected)]. The majority of this increase will however occur in developing countries. Asians, particularly from the Indian subcontinent, will be mostly affected. Reports from different parts of India show a rising trend in the prevalence of diabetes. In 1995, prevalence of diabetes was 19.4 million and is projected to increase to nearly 80 million in 2030. Migrants have a higher risk of developing type-2 diabetes. The long-term impact of obesity and change in diet are two main causes of increased prevalence of diabetes in migrant Indians. The migrants are shifting from the high-fiber staple diet to polished and milled rice.

Diabetes is a heterogeneous syndrome where it is impossible to formulate a unified etiopathogenesis. In our country (India), diabetes of the young is often seen. Type-2 diabetes occurs a decade earlier and type-1 occurs a decade later. In type-2, strong genetic basis exists. But the

time of onset depends on the environmental factors. It is triggered by obesity, increase in age, and diet indiscretion.

In type-1 diabetes, in a susceptible individual (HLA B8), interaction between environmental factors triggers autoimmune response.

Environmental factors play a role in the etiopathogenesis of diabetes. They include polluted air, soil, water, unhealthy diet, stress, lack of physical activity, vitamin-D deficiency, exposure to enteroviruses, and damage to immune cells.

2. Diet

Unhealthy food rich in saturated fatty acids, refined carbohydrates, and sweets cause obesity and DM. Three major dietary toxins that trigger diabetes are cereal grains (especially refined flour), omega-6 industrial seed oils (corn, cottonseed, safflower, and soybean), and fructose (high-fructose in corn syrup). These nutrients in excessive quantities increase the risk of obesity and diabetes, especially if there is genetic risk. These dietary factors increase inflammation and act as potential risk factors for diabetes. A recent study showed that a diet with an omega 6:3 ratio of 28 (meaning 28 times more omega-6 than omega-3 fats) increased obesity in mice in experimental studies [1, 2].

Fructose is found primarily in fruits, vegetables, and sweeteners. Fructose is shunted directly to the liver where it is converted to fat. Excess fructose consumption causes a condition called nonalcoholic fatty liver disease, which is directly linked to both diabetes and obesity. Shifting 25% of dietary calories from glucose to fructose caused a fourfold increase in abdominal fat. Abdominal fat is an independent predictor of insulin sensitivity, impaired glucose tolerance, high blood pressure, high cholesterol and triglyceride. Fructose reacts with polyunsaturated fat and protein to form advanced glycation end-products (AGEs). A donut is the perfect diabetes food. It has refined flour, trans-fatty acids, and plenty of high-fructose corn syrup.

3. Food practices and diabetes

Diet and related factors that promote diabetogenesis:

- Calorie (energy) intake in excess of physical needs leading to obesity
 - Preferential and excess consumption of high-glycemic index carbohydrate rich-food
 - Refined flour, pasta, raw rice
 - Overcooked products of the above by baking or roasting
 - Aerated soft drinks
 - Sweets and free sugar
- High-fat diet with greater content of saturated fats, such as dairy and/or meat fat

- Coconut or palm kernel oil
- Vanaspathi—Hydrogenated oil
- High omega-6 fatty acid intake, particularly corn oil, sunflower oil, and saffola
- Energy-dense fat- and sugar-rich snacks and meals at fast-food outlets
- Reduced consumption of legume, fresh fruits, and vegetables

4. Secondary causes

Low protein diet impairs beta-cell function. This phenomenon is shown in rats and rhesus monkeys. Such beta-cell dysfunction in case of malnutrition in utero as well as in infancy and early childhood has been projected as the basic mechanism in the pathogenesis of malnutrition-modulated DM seen among the poor in some tropical areas [3].

Stress hormones like adrenalin and cortisol can increase blood sugar. Stress causes the liver to release more glucose. In individuals with family history of diabetes, stress can definitely precipitate DM.

4.1. Infant nutrition and type-1 DM

Autoimmune damage to islet cells responsible for type-1 diabetes may have a nutritional basis. Clinical presentation of type-1 DM peaks around puberty or sometime later, but islet cell antibodies are seen by the age of 5 years. The implication is that the involvement of type-1 islet is early in life but may burn faster in some than in others. An association between bottle-feeding and type-1 DM has been found in Finland. It is hypothesized that molecular mimicry between islets antigen P69 and bovine serum albumin in cow's milk may occur.

4.2. Fibrocalculous pancreatic diabetes (FCPD)

Chemicals	Altered beta-cell function
a) Rodenticide	a) Calcific fibrosis
b) Streptozotocin	b) Cassava
c) Nitrosamine	c) Protein malnutrition

Table 1. Beta cell damage caused by:

Malnutrition = Cassava intake.

Cassava (tapioca) contains linamarim, a cyanogenic glycoside, which on hydrolysis releases hydrocyanic acid. This hydrocyanic acid is normally inactivated by conjugation with sulf-hydryl radicals derived from aminoacids—methionine and cysteine, and combines with hydrocyanic acid to form thiocyanate, which is excreted in urine. In protein-calorie malnutri-

tion, there is a deficiency of these aminoacids, and accumulation of hydrocyanic acid occurs which may damage the pancreas.

4.2.1. Rich food sources of cyanide

Cassava (Tapioca), sorghum, yam, millet, some varieties of beans are some of the rich sources of cyanide.

4.3. Prenatal infections and diabetes

Child whose mother is type-1 is less likely to develop DM than when the father is affected. Risk is increased with higher birth weight in elderly parents.

4.4. Role of demographic factors in diabetes etiology

There is an increased incidence of incidence of type 1 DM in spring and autumn season; probably related to viral infection. Viral infections through autoimmune mechanisms or directly damaging beta cell may precipitate diabetes. Most of the viral infections are asymptomatic and may precipitate diabetes even after several years of diabetes. Prenatal infections of viruses such as congenital Rubella, cytomegalovirus, and enterovirus are known to be diabetogenic.

4.4.1. Virus and beta-cell damage

- Virus persists in host, leading to protracted beta-cell dysfunction
- Virus directs acute beta-cell destruction
- Virus activates beta-cell defense mechanism, leading to inflammatory cytokines
- Virus produces immune-mediated beta-cell destruction [4]

4.5. Insulinitis

Activated T-lymphocytes infiltrate the pancreatic islets prior to or spontaneous with the development of diabetes. Islet inflammation leading to beta-cell failure is a factor in pathogenesis. Interleukin (IL)-1 is central to this insulinitis. Islet infiltrating macrophages are a major source of IL-1 and other cytokines in response to elevated levels of glucose and saturated fatty acids. IL-17A exacerbates proinflammatory chemokine expression and secretion by human islets exposed to cytokines. This suggests that IL-17A contributes to the pathogenesis of type-1 diabetes by two mechanisms, namely the exacerbation of beta-cell apoptosis and increased local production of chemokines, thus potentially aggravating insulinitis.

- Exposure to cow's milk in infancy may precipitate DM. Coeliac disease and type-1 DM can overlap with the haplotypes [5–8].

- **Vitamin D:** Type-1 DM patients have low vitamin D levels, and lack of sunlight correlates well with increased incidence of type-1 DM at higher altitudes [9–14]. Young people who have higher vitamin D levels have lesser chances of developing T2DM later in life, compared to people who have lower vitamin D levels. People with newly diagnosed type-2 diabetes often have low vitamin D levels than people without diabetes. Vitamin D may have a role in pancreatic beta-cell function, insulin action, and inflammation. There are some specific receptors in pancreatic beta-cell that start turning on if they get enough vitamin D. There is an association between low vitamin D and decreased insulin sensitivity. Vitamin D plays an important part in the regulation of calcium. Calcium helps to control the release of insulin; so, alterations in calcium can have a negative effect on beta-cell function. People with higher vitamin D in blood, that is, over 25 ng/ml had a decreased chance of getting type-2 DM later in life compared to those with lowest levels, that is, below 14 ng/ml. A person with highest vitamin D level in blood had a 19% decreased chance of developing type-2 DM. For every 4 ng/ml increase in vitamin D, there was 4% lower risk of developing type-2 DM. In one study, it was shown that vitamin D supplementation improved pancreatic beta-cell function [15–18].
- High vitamin E levels are associated with diabetes, and beta-carotene, the precursor of vitamin A, is a protective factor in diabetes prevention.
- Overweight and inactivity results in insulin resistance and diabetes.
- Age: with increasing age, risk of diabetes increases. Increased triglyceride increases the risk of type-2 diabetes.

4.6. Drugs

Drugs like thiazide diuretics, diphenylhydantoin, pentamidine, and cyclosporin may cause diabetes. Experimental chemical agents that induce diabetes are afloxan and streptozotocin.

4.6.1. Advanced glycation and lipoxidation end-products (AGEs and ALEs) as dysmetabolic risk factors

AGEs are not only endogenously produced but also have an exogenous origin. Thermally processed food products contain high amounts of heat-accelerated protein and lipid-associated pro-oxidant. Foods rich in exogenous AGEs and ALEs are foods cooked at high temperature, roasted foods, fried foods, and dairy products processed with sugar [19].

AGEs and ALEs add to the systemic toxic pool of these powerful pro-oxidants. The glycoxidation product may be considered an important risk factor for insulin resistance, diabetes, and other chronic illness. Increased concentrations of reactive carbonyl compounds have been observed in patients with diabetes, leading to the formation of various AGEs in the body. Both AGER1 (advanced glycation receptor-1) and SIRT1 (survival factor sirtuin 1) were independently found to be suppressed in chronic oxidative stress conditions like diabetes and ageing. AGEs may contribute to insulin resistance. It seems plausible that excess intra-adipose AGEs could impair normal lipolysis via suppression of SIRT1, a factor implicated in fatty acid mobilization. AGEs deplete host defenses, raise basal oxidative stress and inflammation, and

increase susceptibility to dysmetabolic insulin resistance. Pyridoxamine was observed to decrease AGEs accumulation. AGEs are increasingly considered in the pathogenesis of cardiomyopathy, retinopathy, and nephropathic complications of diabetes. AGE levels correlate with these complications.

Restriction of AGEs would result in increased expression of SIRT1 and AGER1 and reduction in insulin resistance . AGE inhibition and Sirtuin activation will be the targets of treatment in future for DM.

Urbanization has been recognized as a potent environmental predisposing factor for the development of type-2 DM. Urban rural differences in the prevalence of diabetes in the same community have been highlighted in most of the epidemiological studies.

S.No.	Protecting factors	Precipitating factors
1	Breast-feeding	Cows’ milk allergy
2	Nicotinamide	Infant feeding through bottle-milk
3	Zinc	Weight gain in infancy
4	Vitamin C, D, and E	Enterovirus infection during pregnancy
5	–	Preeclampsia
6	-	Excessive weight gain in pregnant women
Environmental agent		Diabetogenic effect
Viruses		Increase
• Rubella		Increase
• Enteroviruses (Coxsackie B, Echoviruses)		Increase
• Cytomegalovirus, mumps, retroviruses, rotaviruses		
Diet		Increase
• Cow’s milk		Increase
• Early cereal supplements		Increase
• N-nitroso compounds		
• Vitamin D deficiency		
Childhood vaccination		No effect
Older maternal age		Increase
Increase birth weight (large babies) (more than 4 kg / 8lb 13 ounce)		Increase

Table 2. Nutritional risk factors in type-1 DM.

4.7. Gut microbes and type-2 diabetes

Gut microbiota–host interactions control energy homeostasis, glucose metabolism, and lipid metabolism. In addition to genetic and environmental factors, gut microbes may play an important role in the modulation of metabolic diseases. It was found in type-2 diabetes by a moderate degree of gut microbial dysbiosis, decrease in the abundance of some universal butyrate-producing bacteria and increase in various opportunistic pathogens, conferring sulfate reduction and oxidative stress resistance in a Chinese study. Obese people with insulin resistance have in their gut elevated firmicutes/bacteroidetes ratio when compared with healthy people. Change in gut microbes in obese people modulates intestinal permeability and increases metabolic endotoxin secretion that leads to chronic low-level inflammation, leading to insulin resistance and type-2 diabetes. Probiotic strains modulate immune system, down-regulate inflammatory interferon (IFN)- α and IL-2 or IL-1 β , and enhance anti-inflammatory IL-10 production [20].

It was found that *Saccharomyces boulardii*-treated mice exhibited reduced fat mass, reduced hepatic steatosis, and reduced inflammatory reaction, thereby concluding this probiotic will prove beneficial to the treatment of obesity and type-2 diabetes.

Nutrition during fetal life and infancy may be crucial to the development of DM; infants who are small for dates (a marker for poor intrauterine nutrition) have fewer beta-cells. Impaired glucose tolerance and type-2 DM may both result from poor nutrition early in life interacting adversely with abundant nutrition later on. Obesity in late years leads to insulin resistance.

4.7.1. Night-shift workers and diabetes

Men who work on shifts face a massively increased risk of developing diabetes. Shift-working men face a 37% increased risk of developing diabetes compared to general population with an overall increased risk of 9%. Shift workers tend to put on weight and suffer from increased appetite. Rotating shifts make it harder for people to adjust to a regular sleep–wake cycle. Lack of sleep or poor quality of sleep may worsen insulin resistance. Night-shift workers have higher risk of developing obesity, DM, and sleep problems [21].

While multiple genetic loci may operate in combination with environmental factors to produce diabetes, other determining factors are age of onset, severity, and rate of progress. Developments in diabetogenesis occur slowly to manifest characteristic abnormalities like IFG, IGT, frank diabetes, and lipid abnormalities. These changes take 7–8 years to progress into diabetes.

The most important promoters of metabolic syndrome and diabetes identified among environmental factors are lifestyle changes and dietary practice. Principal changes in diet consists of greater consumption of calorie-dense foods, particularly fast-foods with greater fat and refined carbohydrate contents, and decreased preference for natural fiber-containing whole grain products, fruits, and vegetables with low glycemic index. These dietary changes lead to obesity and dyslipidemia and glucose intolerance, which are characteristic of type-2 diabetes.

4.7.3. *Physical inactivity*

Sedentary life style with constant use of automobiles even for short distances, sitting long hours at office/study table, and more so in watching television and using computers have transformed the lives of most urbanites, starting from childhood throughout the rest of their life. These practices have increased the incidence of diabetes and heart disease. Increased physical activity by regular walking, gardening, and doing both endurance and resistance types of exercises have been found to prevent the onset of diabetes.

4.7.4. *Obesity and BMI*

Risk of diabetes is estimated to increase by 9% for every increase in 1 kg body weight. Obesity alone accounts for nearly 64% of diabetes in men and 74% in women. Independent of BMI, android distribution of fat and waist circumference predict diabetes risk. Obesity predisposes to insulin resistance and beta-cell failure.

4.7.5. *Exposure to chemicals*

Chemicals from water pollution, plastic packaging, cleaning and beauty care products have all been found to increase insulin resistance and diabetes.

Persistent organic pollutants (POPs) are pollutants that accumulate in the environment due to extensive use of pesticides and industrial chemical products. Pollutants in the environment, consumer products, and cosmetics may all increase risk of diabetes. Endocrine-disrupting chemicals are the substances present in the environment, food, and consumer products, which have the ability to affect hormone production and metabolism among other functions. Type-1 DM is seen more in people who consume fish that have higher amounts of heavy metal pollutants like cadmium and lead present in them. Plastic bottles used for water-storing are known to give out Endocrine-Disrupting Chemical (EDC) [22–25]. Europe has moved away from plastic to glass. There is a connection between pollution and obesity. They are implicated in immune dysfunction and type-2 DM. The organic pollutants are present in animal fats, which when consumed can cause diabetes by producing insulin resistance. Obesity per se may not cause DM, but the presence of POPs in obese people make them susceptible for the development of diabetes. The best preventive measure against POP-induced diabetes will be to minimise the use of pesticides and saturated fats [26–31].

POPs include hundreds of different chemical compounds with common properties, such as long-term persistence, widespread diffusion in the environment, and bioaccumulation through the food chain. These POPs which are cytochrome P450 enzyme inducers are found in the environment, either in the air, soil, or water. They accumulate in the body as white adipose tissue (WAT), which acts as a reservoir of lipophilic environmental pollutants. They are resistant to biological and chemical degradation, leading to their accumulation. They are detectable in virtually all of the general population, most of who experience only background exposure through food consumption, but their persistence has led to multiple health effects, including diabetes. A total of 12 POPs, all chlorine-containing organic compounds, have been

chosen as priority pollutants by the United Nations Environment Program (UNEP) for their impact on human health and environment. These POPs have been divided as follows:

- Pesticides: Aldrin, dieldrin, endrin, chlordane, DDT, heptachlor, mirex, toxaphene and hexachlorobenzene (HCB) [32–38]
- **Industrial chemical products:** Polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB)
- **Unwanted by-products:** Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB)

4.8. Adverse effects on human health

High-dose acute exposure results from accidental fires or explosions of electrical capacitors or other PCB-containing equipment, or food contamination.

Mid-level chronic exposure is predominantly due to the occupational exposure or increased consumption of POP-contaminated dietary source, such as fish or other marine animals.

Chronic, low-dose exposure is seen worldwide in most of the population in different quantities, depending on the variations of diet, geography, and the level of the industrial pollution.

Short-term exposure to high concentrations of certain POPs has been shown to result in illness and death. In 1990, Rice farmers and mango sprayers of Philippines suffered acute endosulfan poisoning.

Chronic exposure to sublethal concentrations of POPs over prolonged exposure can cause the following:

- Immune dysfunction
- Dermatological effects like chloracne
- Neurodevelopmental and neurobehavioral effects
- Reproductive anomalies
- Endocrine problems
- Rheumatological disorders like arthritis
- Carcinogenesis

Swedish investigations have reported that dietary intake of PCBs (polychlorinated biphenyls), dioxins, and furans may be linked to important reductions in the population of natural killer cells (lymphocytes). Studies of high-level exposure also indicate that some biochemical changes, for example, in enzyme and hormone levels may be induced.

Very high levels of dioxin (2, 3, 7, 8-TCDD), hundreds of times greater than natural levels, are known to cause a reversible skin condition known as chloracne (acne-like eruption of blackheads, cysts, and pustules). Lifetime presence of chloracne, abnormal nails, hyperkeratosis,

skin allergy, goiter, headache, gum pigmentation, and broken teeth were observed more frequently in the men and women exposed to PCB/PCDF. The exposed women reported anemia 2.3 times more than controls. The exposed men reported arthritis and herniated intervertebral disks 4.1 and 2.9 times, respectively, more than controls. The developing fetuses and neonates are particularly vulnerable to POPs' exposure due to transplacental and lactational transfer of maternal POP, some of which can potentially affect neurodevelopment.

4.9. POPs and diabetes

Dae-Hee Lee and colleagues were the first to analyze serum concentrations of POPs which showed the prevalence of DM more than five times higher in groups with higher concentrations of PCB153, oxychlordane, or trans-Nonachlor than in those with lower concentrations. In a study, they found a strong dose-response relationship between diabetes and the six POPs (one PCB (hexachlorobiphenyl), two dioxins (heptadioxin and OCD dioxin), two pesticides (oxychlordane and trans-Nonachlor), and a pesticide metabolite (DDE, a metabolite of DDT)) [5]. In general, older people had higher levels of individual contaminants than younger people. Men tended to have lower concentrations compared to women. For all but one contaminant (PCB153), Hispanics tended to have higher levels as did poorer people [36–38].

The various mechanisms implicated by these POPs in causing diabetes are as follows:

- Insulin resistance
- Obesity
- Decreased insulin production
- Disrupted glucose homeostasis

4.9.1. *Insulin resistance*

Serum concentrations of organochlorine (OC) pesticides were found to be strongly and positively associated with insulin resistance among nondiabetic subjects. Results suggest that the background environmental exposure to some POPs, especially OC pesticides, may be critically involved in the pathogenesis of diabetes through a pathway involving insulin resistance. Among several OC pesticides, both oxychlordane (metabolites of chlordane) and trans-Nonachlor (impurity of chlordane) were most strongly associated with insulin resistance. Individuals with high levels of POPs (DDT, dioxins, PCBs, and chlordane, among others) in their body were found up to 38 times more likely to be insulin-resistant than individuals with low levels of these pollutants, though a cause and effect relationship could not be established.

4.9.2. *Obesity*

Because POPs are lipophilic, people with higher body mass index may be more likely to store higher levels of these organic pollutants than people with lower body mass index with equivalent exposure. A study by the National Health and Nutrition Examination Survey on

population found that obesity and diabetes were associated only among participants with detectable levels of POPs [5]. The diabetogenic effect due to dioxin exposure has also been shown to be stronger among obese compared with lean individuals. Another possibility is that insulin resistance causes increased accumulation of POPs. Obesity was associated with diabetes only in people who tested high for these pollutants. Lee et al. found no association between obesity and diabetes in individuals with nondetectable levels of POPs. Obesity was a risk factor for diabetes only if people had blood concentrations of these pollutants above a certain level. Thus, this indicates that obesity is only a vehicle for the accumulation of POPs in the body which eventually results in diabetes.

4.9.3. Decreased insulin production

Pancreatic β -cells contain muscarinic acetylcholine receptors, which are involved in the glucose-dependent production of insulin. Organophosphate insecticides are known inhibitors of acetylcholinesterase, the enzyme responsible for the degradation of acetylcholine. Thus, exposure to sufficiently high levels of organophosphate insecticides would be expected to result in increased accumulation of acetylcholine, potentially leading to overstimulation and eventual downregulation of its receptors and reduction in insulin production.

4.9.4. Disrupted glucose homeostasis

Dioxins are known to be a frequent contaminant of herbicides and have been used in the past as a contaminant by the name of Agent Orange (a code name used by the military) [16, 17]. It involves an estrogen-dependent peroxisome proliferator-activated receptor (PPAR) pathway and thereby upregulates insulin-like growth factor binding protein-1 (IGFBP-1) in MCF-7 cells. Studies have suggested that exposure to these contaminated herbicides increased the risk of diabetes by disrupting the glucose and insulin homeostasis.

4.10. Prevention and control

International efforts to minimize exposure to these compounds include the banning of their use. With the exception of DDT, few, if any, of these compounds have been authorized for use. PCBs, which were widely used in capacitors, transformers, and lubricating oils, have not been manufactured for several decades, but linger in the environment. Chlorinated dibenzodioxins and dibenzofurans are by-products of products made from chlorophenols.

4.10.1. At the individual level

Since fetuses and infants are especially sensitive to the effects of toxic compounds, efforts should be made to reduce girls' and women's exposure to dioxins in foods during the years well before childbearing, so that lesser amounts of these compounds accumulate in their bodies and are passed on through the placenta and breast-milk. Fats in meat, poultry, fatty fish, whole milk, and full-fat dairy products are the principal sources of most people's exposure, and their ingestion should be minimized. Choosing a balanced diet that is low in saturated and total fats

helps minimize any potential exposure to dioxin from food, because dioxins are found mostly in animal fats (due to the fat-soluble properties of the dioxin compound).

- Choose leaner cuts of beef, pork, and poultry; trim the fat and remove skin from chicken before cooking.
- Choose nonfat and low-fat milk and milk products.
- Choose a diet high in fruits, vegetables, whole grains, and lean proteins.

These strategies help lower the intake of saturated fats and total fats and therefore help reduce the risk of exposure to dioxins.

4.10.2. At the industry level

The industries should make an effort to produce alternatives to the banned pesticides which are biodegradable. Research and development for new products should be undertaken rigorously by industries. Training of farmers in terms of efficient and judicious use of pesticides should be undertaken.

Research in the following direction may be useful:

- Serum concentration of POPs in genders, obese and nonobese diabetics, type-1 and gestational diabetics should be studied to find the relationship between POPs and DM.
- Relationship between fatty foods, oil, and water levels of POPs in humans should be studied.

4.10.3. At the government level

The government plays an important role in the prevention of POPs. They should improve the surveillance system to monitor any manufacturing, import, or export of banned pesticides. Carrying out changes according to the POP elimination programs should be their main goal.

5. Conclusion

Environmental factors have a major role both in type-1 and type-2 DM. Even when there is genetic proneness, environmental factors precipitate diabetes. These environmental factors are reviewed in detail. The accumulation of POPs in the environment and their various effects on humans in general have been given in short. Their implications in the causation of type-2 DM, with a special reference to their mechanism, including preventive measures, have been discussed. Further study is needed regarding urban and rural concentrations of POPs as well as study of POPs in type-1 DM, type-2 DM, obese DM, and gestational DM.

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