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The Silent Threat: Chronic Exposure to Chemical Fertilizers and Its Impact on Human Health

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Abstract- The widespread use of chemical fertilizers has revolutionized agriculture, significantly increasing crop yields and supporting the global food supply. However, the chronic exposure to these chemicals poses a silent but significant threat to human health. This paper explores the various pathways through which chemical fertilizers affect human health, examines the long-term health implications, and suggests potential measures to mitigate these risks. The review synthesizes existing research on the subject, highlighting the need for more comprehensive studies and the development of sustainable agricultural practices that prioritize human health.

Keywords: chemical fertilizers, revolutionized agriculture, human health, sustainable agricultural,

I. INTRODUCTION

Fertilizer is a substance added to soil or plants to supply essential nutrients that enhance plant growth and yield. Fertilizers are crucial in agriculture to ensure crops receive the right balance of nutrients, particularly in areas where soils may be lacking. They contain main primary plant macronutrients like nitrogen, phosphorus, potassium, secondary plant macronutrients calcium, magnesium, and sulphur and micronutrients like copper, iron, manganese, molybdenum, zinc, and boron. In general, fertilizers can be categorized as organic fertilizers and chemical (or inorganic) fertilizers [4]. Organic fertilizers are not used commercially due to lower productivity [1, 2]. According to application methods the fertilizer are of four types that is broadcasting (Spreading fertilizer), side dressing (Applying fertilizer), foliar feeding (Spraying liquid fertilizers) and soil injection (Injecting liquid fertilizers) [5].

Chronic exposure to chemical fertilizers can have various impacts on both human health and the environment [31]. It have great impact on human health as respiratory issues, skin and eye irritation, nitrate contamination, gastrointestinal issues etc. These chemicals poses a silent but significant threat to human health [29]. Farmers try to grow more crops (to get good yield) and use more and more chemical fertilizers like Ammonium nitrate, calcium ammonium nitrate, calcium nitrate, monoammonium phosphate, diammonium phosphate, urea, triple superphosphate, di ammonium phosphate (DAP) etc. [30].

The global demand of food has led to the intensive use of chemical fertilizers, which has become an integral part of modern agriculture [26].While these fertilizers have played a crucial role in boosting agricultural productivity, their extensive use has raised concerns about their impact on human health [27]. This paper aims to explore the chronic health risks associated with chemical fertilizers, focusing on the long-term effects of exposure to these chemicals on various human systems.

Scientific development of synthetic nitrogen fertilizer has significantly supported global population growth [40]. It has been estimated that almost half the people on the Earth are currently taking food grown using nitrogen fertilizer. The use of phosphate fertilizers has also increased from 9 million tonnes per year in 1960 to 40 million tonnes per year in 2000 (Fertiliser Association of India. 2003/04). Agricultural use of inorganic fertilizers in 2021 was 195 million tonnes of nutrients, of which 56% was nitrogen. Asia represented 53% of world total agricultural use of inorganic fertilizers in 2021, followed by the Americas (29%), Europe (12%), Africa (4%) and Oceania (2%) [6, 7]. This ranking of the regions is the same for all nutrients. The main users of inorganic fertilizers are, in descending order, China, India, Brazil and the United States of America (see Table 15), with China the largest user of each nutrient [25].

II. CHEMICAL COMPOSITION OF FERTILIZERS

Chemical fertilizers are primarily composed of nitrogen (N), phosphorus (P), and potassium (K), often referred to as NPK fertilizers (Table-1) [30].

Three main macronutrients (NPK):

- **Nitrogen (N):** leaf growth and stems.
- **Phosphorus (P):** development of roots, flowers, seeds, fruit;
- **Potassium (K):** strong stem growth, movement of water in plants, promotion of flowering and fruiting;
- Three secondary macronutrients: calcium (Ca), magnesium (Mg), and sulphur (S);
- micronutrients: copper (Cu), iron (Fe), mangane se (Mn), molybdenum (Mo), zinc (Zn), boron (B) . Of occasional significance are silicon (Si), cobalt (Co), and vanadium (V) [32].

Additionally, they may contain secondary nutrients like calcium, magnesium, and Sulphur, as well as trace elements such as zinc and manganese (Table-2 and Graph-2) [31].

However, these fertilizers often include contaminants like heavy metals (e.g., cadmium, lead, and arsenic) and other harmful substances, which can pose significant health risks when humans are exposed to them over extended periods. Top users of nitrogen based fertilizers, China is on the top and India is on second number (Table-3 and Graph-3)

III. PATHWAYS OF HUMAN EXPOSURE

Human exposure to chemical fertilizers can occur through various pathways, including:

Contaminated Water Supply: Runoff from agricultural fields can lead to the contamination of groundwater and surface water with nitrates and other harmful chemicals, which are then consumed by humans. According to [8] nitrogen (N) in the form of nitrate is a common pollutant in both surface and ground waters. Nitrate-N can readily absorb by the root zone in agricultural soils and reach the ground and surface waters. Nitrate pollution of ground and surface water bodies all over the world is generally linked with continually increasing global fertilizer nitrogen (N) used [35]. But after 1990, with more fertilizer N consumption in developing countries especially in east and south Asia than in the industrialized nations in North India, Pakistan and Bangladesh, nitrate pollution of freshwaters is now increasingly becoming a pervasive global problem [28]. At levels exceeding the permissible limits, nitrate-N makes the ground water unfit for drinking purposes.

Food Chain Contamination: Crops grown with chemical fertilizers may absorb toxic substances, which can then accumulate in the human body through the consumption of these contaminated foods. Fertilizers and soil amendments can contain trace elements like phosphates, zinc, and manure that can contaminate the food chain and harm humans, animals, and wildlife [37]. Cd disease has only been found in subsistence rice consumers with industrially-contaminated paddy soils [34]. Cd–Zn mine waste contamination of rice soils in Asia caused excessive accumulation of Cd but not Zn in rice grain, such that subsistence farm families suffered Cd health effects [24].

Airborne Exposure: Dust and particles from chemical fertilizers can become airborne during application or from treated soils, leading to inhalation by nearby populations. Human health impacts of fertilizer dust emissions can be far-reaching and devastating. Inhalation of airborne particles can cause damage to the lungs, leading to serious respiratory illnesses such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) [19]. Study demonstrates that dairy farming is associated with an increased risk of lung disorders and a decrease in blood oxygen saturation and suggests that respiratory function impairment is correlated with cumulated exposure to organic dusts.

Occupational Exposure: Farmers and agricultural workers who handle and apply fertilizers are at higher risk of direct exposure, potentially leading to chronic health issues [16,20]. The study that Fertilizers, especially when handled improperly or without adequate protective measures, can pose health risks to workers. These risks depend on the type of fertilizer, its chemical composition, and the manner in which it is handled like Nitrogen-based fertilizers (Ammonium nitrate, urea, and ammonium sulphate), Phosphorus-based fertilizers (Ammonium nitrate, urea, and ammonium sulphate), Potassium-based fertilizers (Potassium chloride and potassium sulphate), Micronutrient fertilizer (metals like copper, zinc, or iron), and Organic fertilizers (like compost, manure, or bone meal are less toxic but still carry risks) [21, 22].

IV. Health Impacts of Chronic Exposure

The chronic exposure to chemical fertilizers has been linked to a variety of adverse health effects:
Respiratory Issues: Inhalation of fertilizer particles can lead to respiratory problems, including asthma, bronchitis, and other chronic respiratory conditions. Endocrine Disruption: Some chemical fertilizers contain substances that can interfere with the endocrine system, leading to hormonal imbalances and reproductive issues [13].

Cancer Risk: Prolonged exposure to certain chemicals in fertilizers, particularly nitrates and heavy metals, has been associated with an increased risk of cancers, including gastrointestinal and bladder cancers [23]. The study and examined respiratory and dermal health associated with fertilizer exposure among tree planters. Studied cause of skin irritation and skin sensitization [3].

Neurotoxicity: Chronic exposure to heavy metals and other toxic substances in fertilizers can lead to neurodegenerative diseases and cognitive impairments. Study that higher level exposures that result from occupational exposures and proximity to agricultural spraying are associated with several neurotoxicities in humans [17]. To set environment the many to increase crop yields [9].

Cardiovascular Disorders: Studies have shown a correlation between high nitrate levels in drinking water and an increased risk of cardiovascular diseases, including hypertension and heart attacks. Studied the impact of organic fertilizers on nutrition and health outcomes [11,15], Studied that Optimization of plant nutrition using non-traditional organic fertilizers and zeolite.

V. CASE STUDIES AND EPIDEMIOLOGICAL EVIDENCE

Numerous case studies and epidemiological research have documented the health impacts of chronic exposure to chemical fertilizers. For example, studies in agricultural communities have shown higher incidences of respiratory problems and cancers among populations with prolonged exposure to fertilizers. Additionally, research in regions with high levels of nitrate contamination in drinking water has linked these conditions to adverse birth outcomes and increased cancer risks [36].

VI. MITIGATION STRATEGIES

To reduce the health risks associated with chemical fertilizers, the following strategies are recommended:
Promotion of Organic Farming: Encouraging the use of organic fertilizers and sustainable farming practices can significantly reduce the reliance on chemical fertilizers [43].

Regulation and Monitoring: Strengthening regulations on the use and composition of chemical fertilizers, along with regular monitoring of water and soil quality, can help mitigate contamination risks.

Public Awareness: Educating farmers and the general public about the health risks associated with chemical fertilizers and promoting safe handling practices can reduce exposure levels [18].

Research and Innovation: Investing in research to develop safer, more sustainable alternatives to chemical fertilizers is crucial for long-term health and environmental sustainability [17].

Eco-friendly fertilizers

Eco-friendly fertilizers, derived from natural sources such as compost, manure, vermicompost, biofertilizers, and green manure, serve as a linchpin for sustainable agriculture. Their integration into farming systems addresses environmental, social, and health challenges, aligning with global sustainability goals [14, 17]. This discussion synthesizes their multifaceted contributions, challenges, and potential for transformative impact.

Environmental Sustainability

Eco-friendly fertilizers significantly bolster environmental sustainability by mitigating the ecological damage caused by synthetic fertilizers [39]. They enhance soil health through increased organic matter, improving structure, water retention, and microbial diversity, which supports long-term fertility and carbon sequestration [42]. By reducing chemical runoff, these fertilizers prevent water pollution and eutrophication, safeguarding aquatic ecosystems. However, challenges such as slower nutrient release and scalability issues limit their adoption, particularly in intensive farming systems. Economic pressures often favour short-term, high-yield synthetic options, underscoring the need for policy incentives and education to promote sustainable practices [43].

Social and Health Benefits

The social and health benefits of eco-friendly fertilizers extend beyond agriculture, fostering resilient communities and safer food systems. Health-wise, they reduce chemical residues in crops, lowering risks of pesticide-related illnesses like neurological disorders and cancers, while producing nutrient-rich produce to combat malnutrition [42]. socially, local production of organic fertilizers creates jobs and encourages community-based farming, enhancing self-reliance and preserving traditional agricultural knowledge. Consistent crop yields from improved soil fertility strengthen food security, particularly in vulnerable regions. Yet, limited awareness and access to these fertilizers in low-income areas pose barriers, necessitating targeted outreach and support.

Eco-Friendly Fertilizers: Opportunities and Challenges

Eco-friendly fertilizers offer a sustainable alternative to synthetic inputs, reducing dependency on energy-intensive production and aligning with organic certification standards [10]. Their diverse type’s compost, manure, vermicompost, biofertilizers, and green manure—cater to varied agricultural needs, promoting biodiversity and cost-effectiveness for small-scale farmers. However, high initial costs for production systems and limited access to advanced biofertilizer technologies hinder widespread adoption [33, 34]. The slower nutrient release may not meet the demands of high-intensity agriculture, requiring innovations in formulation and application techniques.

Integrated Perspective

The synergy of environmental sustainability, social and health benefits, and eco-friendly fertilizers highlights their potential to reshape agriculture. By addressing soil degradation, pollution, and health risks, these fertilizers support a holistic approach to sustainability [38]. Their role in empowering communities and ensuring food security further amplifies their significance [12]. To overcome barriers, governments and organizations should prioritize subsidies, research into cost-effective technologies, and educational campaigns to raise awareness. Global cooperation to share best practices can accelerate adoption, aligning with initiatives like the United Nations’ Sustainable Development Goals [41].

VII. CONCLUSION

While chemical fertilizers have undeniably contributed to the global food supply, their chronic use poses a significant threat to human health. The evidence suggests that long-term exposure to these chemicals can lead to serious health issues, including respiratory problems, cancer, endocrine disruption, and neurological disorders. Addressing these risks requires a multifaceted approach, including the promotion of sustainable farming practices, stricter regulations, and increased public awareness. Further research is needed to fully understand the long-term health impacts of chemical fertilizers and to develop safer alternatives that prioritize both agricultural productivity and human health. Eco-friendly fertilizers are a cornerstone of sustainable agriculture, offering interconnected benefits across environmental, social, and health domains. While challenges like cost, awareness, and scalability persist, strategic interventions can unlock their full potential. By fostering innovation and policy support, eco-friendly fertilizers can drive a global shift toward greener, healthier, and more equitable food systems.

Now a days biofertilizers are a sustainable and eco-friendly alternative to chemical fertilizers, offering significant benefits for agriculture and the environment. They enhance soil fertility by improving nutrient availability, particularly nitrogen and phosphorus, through microbial activities like nitrogen fixation, phosphate solubilization, and organic matter decomposition. Key advantages include increased crop yield, improved soil health, and reduced environmental pollution due to lower chemical inputs. They promote beneficial microbial activity, enhance plant growth through hormone production, and support long-term soil sustainability. However, challenges such as limited shelf life, variable efficacy under different soil conditions, and the need for farmer education on application methods can hinder widespread adoption. Despite these limitations, biofertilizers hold immense potential for sustainable agriculture, especially when integrated with organic farming practices and modern agricultural techniques. Scaling their use requires addressing production costs, improving formulations for stability, and increasing awareness among farmers to ensure effective implementation.

Table- 1

Nutrient Family	Nutrient	Percentage of plant	Form taken up by plant (ion)	Mode of uptake	Major functions in plants
Primary	Carbon	45	Carbon dioxide (CO_2), bicarbonate (HCO_3)	Open somates	Plant structures
Primary	Oxygen	45	Water (H_2O)	Mass flow	Respiration, energy production, plant structures
Primary	Hydrogen	6	Water (H_2O)	Mass flow	pH regulation, water retention, synthesis of carbohydrates
Primary	Nitrogen	1.75	Nitrate (NO_3), ammonium ($NH4^+$)	Mass flow	Protein/amino acids, chlorophyll, cell formation
Primary	Phosphorous	0.25	Dihydrogen phosphate ($H_2PO_4^-$, HPO_4^{2-}), phosphate (PO_4^{3+})	Root interception	Cell formation, protein syntheses, fat and carbohydrate metabolism
Primary	Potassium	1.5	Potassium ion (K^+)	Mass flow	Water regulation, enzyme activity
Secondary	Calcium	0.5	Calcium ion (Ca_2^+)	Mass flow	Root permeability, enzyme activity

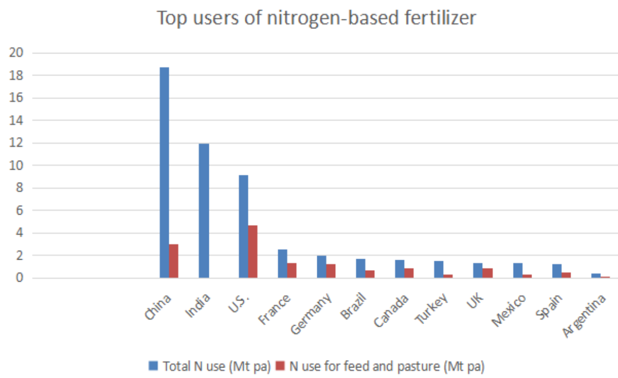
Secondary	Magnesium	0.2	Magnesium ion (Mg^{2+})	Mass flow	Chlorophyll, fat formation and metabolism
Secondary	Sulfur	0.03	Sulphate (SO_4^{2-})	Mass flow	Protein, amino acid, vitamin and oil formation
Micro	Chlorine	0.01	Chloride (Cl^-)	Root interception	Chlorophyll formation, enzyme activity, cellular development
Micro	Iron	0.01	Iron ion (Fe^{2+}, Fe^{3+})	Root interception	Enzyme development and activity
Micro	Zinc	0.002	Zinc ion (Zn^{2+})	Root interception	Enzyme activity
Micro	Manganese	0.005	Manganese ion (Mn^{2+})	Root interception	Enzyme activity and pigmentation
Micro	Boron	0.0001	Boric acid (H_3BO_3), borate (BO_3^{3-}), tetraborate (B_4O_7)	Root interception	Enzyme activity
Micro	Copper	0.0001	Copper ion (Cu^{2+})	Mass flow	Enzyme activity
Micro	Molybdenum	0.00001	Molybdenum ions ($HMoO^{4-}$, MoO_4^{2+})	Mass flow	Enzyme activity and nitrogen fixation in legumes

Bulk blending. Ingredient kg/ton				
Blend ingredient	NPK 17-17-17	NPK 19-19-19	NPK 9-23-30	NPK 8-32-16
ammonium nitrate	310			
urea		256		
diammonium phosphate (DAP)	376	421	500	462
triple superphosphate				261
potassium chloride	288	323	500	277
filler	26			

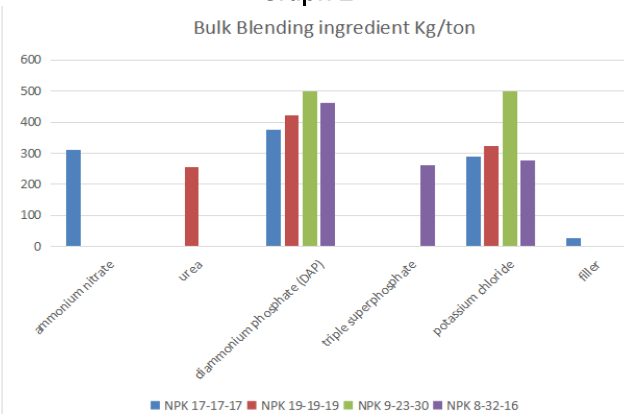
Top users of nitrogen-based fertilizer		
Country	Total N use (Mt pa)	N use for feed and pasture (Mt pa)
China	18.7	3
India	11.9	n/a
U.S.	9.1	4.7
France	2.5	1.3
Germany	2	1.2

Brazil	1.7	0.7
Canada	1.6	0.9
Turkey	1.5	0.3
UK	1.3	0.9
Mexico	1.3	0.3
Spain	1.2	0.5
Argentina	0.4	0.1

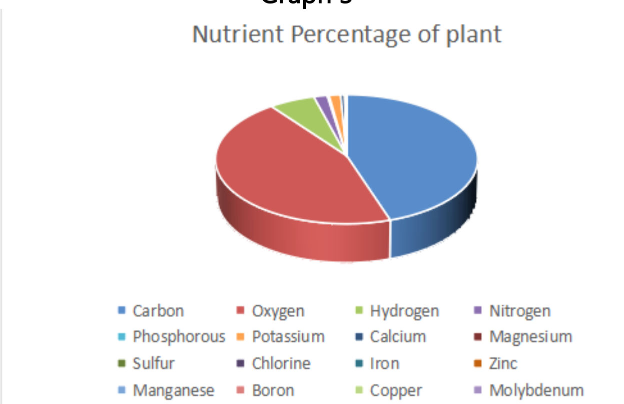
Graph 1



Graph 2



Graph 3



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