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Ecological Crisis Due to Chemical Toxicity: Addressing Soil Health for Better Human Health

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Abstract

When environmental changes undermine a species' or population's ability to survive, it is said to be in an ecological crisis. Pesticides, particularly persistent organic pollutants (POPs), are among the top ten chemicals and hazardous compounds that the WHO has recognized as being a concern for global health. The overuse and improper handling of agrochemicals is the primary driver of the ecological disaster. According to the GBD 2019, pollution of any type, including air pollution, lead, and other chemicals, causes one in six deaths globally. Industrialization, urbanization, population growth, the burning of fossil fuels, and a lack of adequate national or international chemical policies account for the 66% increase in deaths. Because of lack of awareness, training, and proper expertise regarding agrochemicals, it is particularly challenging to determine the influence on human health or the environment in developing nations. Studies in Northern India have shown evidence of the presence of heavy metals and pesticides in samples of fodder, vegetables, milk, urine, and blood. In addition to signs of genotoxic effect, there were significantly more spontaneous abortions, premature births, stillbirths that were five times as frequent, delay in milestone development, language delays, blue lines in the gums, mottled teeth, and gastrointestinal diseases, which may have been brought on by water contamination with pesticides and heavy metals. The greater rates of cancer including breast, uterus/cervix, ovary cancers of the blood and lymphatic system, oesophagus, and bones, are associated with farming, pesticides exposure, alcohol and smoking. Hence the soil and water have cocktail of pesticides and heavy metals. Pesticides have been widely used, and it is possible to find their remnants in the air, water, and soil. The three most important environmental problems affecting the globe now are pollution, climate change, and biodiversity loss. Various new concepts, including sustainable agriculture reforms and food production that uses sustainable practices, have been inspired by the pressing need for a more sustainable and ecological approach. This review elaborates the extent of pollution due to heavy metals and pesticides with their health impacts and the regulatory measures to overcome this by various methods such as concept of soil security, food security, Natueco farming and multisectoral approach.

Keywords: Soil Health; Pesticide usage; Sustainable development goals; Human health; Chemical toxicity; Sustainable agriculture.

Introduction

In terms of the effects of pesticide use, environmental pollution, and other factors that have an impact on the ecosystem, the relationship between human health and the environment has been well explored. It has been documented

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that long- term and chronic exposure to environmental dangers brought on by harmful agents or indirectly caused by the disruption of an ecosystem that supports and sustains life has a major negative influence on human health. According to the WHO, an estimated 12.6 million people died as a result of working or living in an unhealthy environment in 2012 [1]. Out of total global deaths 1 in 4 deaths are due to environmental risk factors. Environmental risk factors such as pollution of air, water and soil, chemical exposures, climate change, and ultraviolet radiation, which ultimately leads to more than hundred morbidities and injuries [1]. Environment and its related factors are important health related SDG indicators with well-established causal connections to health [2].

Human health and wellbeing are significantly impacted by soil. Soil health means "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans." [3] Healthy soils support a variety of ecosystem-related functions in the environment, including biodiversity, plant-animal productivity, air-water quality maintenance or improvement, and support for human health & habitation. [4]. All living organisms are exposed to various chemicals present in the environment. This is a critical concern of scientific community especially public health that the chemicals which are hormonally active and potentially toxic to human systems especially reproductive systems. [5]. This is associated with adverse health outcomes including increased incidence of gastrointestinal disorders, reproductive toxicity and carcinogenic manifestations. India is the twelfth largest producer of pesticides worldwide [6]. Social determinants of health (SDoH), are "the structural determinants and conditions in which people are born, grow, live, work and age." The important component of SDoH includes food and environmental stability which is directly lined with soil health [7]. The 2009 Declaration of the World Summit on Food Security concluded that ''food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life'' (FAO 2009) [8]. Regarding the connections between human health and soil health, 5 dimensions including soil security referring to capability, condition, capital, connectivity and codification are of importance [9].

This paper will present the status of soil health, its impact, case studies, the challenges including food security and need for action to translate research into practice, longevity of healthy soil necessary for sustainable and adequate food production into the future impacting the human health.

Methods

The review on the social determinants of health in relation to soil health was undertaken. We searched the Internet using key words ("soil health" OR "sustainable agriculture" OR "Chemical toxicity") AND ("human health" OR "social determinants of health" OR "diseases" OR "health impact") and ((((((chemical toxicity) AND human health) OR diseases) OR genotoxicity) OR adverse impact) AND soil health) AND agrochemical) on PubMed and Google Scholar. The reference years were 2004-2024 for the search. Open access website were searched such as National Ministry, Conference proceedings and other agencies involved in soil health, sustainable agriculture, food security, soil security and its association with human health.

Results

Sustainable developmental Goals defines key actions on determinants of health. These also highlights the reduction of inequality in determinants of health as a key priority. It includes supporting the actions described in the Sustainable developmental Goals (No poverty, zero hunger, good health and wellbeing, clean water and sanitation, sustainable cities and communities, climate action, life on land) for Universal Health Coverage and other health services [10]. An ecological crisis is defined in terms of the changes or deviation to the environment which destabilize a species or population relevant to its continued survival and potential destruction sustainable human life [11].

Soil health and agrochemical usage

It has been reported that the Organochlorine pesticides (OCPs) are widely used globally for controlling of agricultural pests and vector borne diseases [12]. These OCPs are very stable compounds with half-lives ranging from a few months to many years and may be up to decades [13]. These led to affect the soil properties and are majorly the key reason for declining crop yields and decreased efficiency in terms of output because of poor soil health. Soil health is majorly declining due to erosion, degradation such as salinization, toxification, acidification, soil compaction, crusting and biological degradation. All these factors are causing less crop yield and therefore are the key factor for increased agrochemical for increased output and protection of the crops. It has been estimated that 2 million tons of pesticides are consumed annually at global level. Out of the total usage 52.8% is in Asia followed by 30% in America, 13.8% in Europe and rest other [14]. Data depicts that the developed countries the consumption of pesticide is 3 quarters of the total pesticide usage globally (USEPA, 2009) [15]. Overall, at global level, the pattern of agrochemical usage is that out of all usage is herbicides (47.5%), insecticides (29.5%), fungicides (17.5%) and others (5.5%) [15]. China, USA, Argentina, Thailand, Brazil, Italy, France, Canada, Japan and India are amongst the top 10 pesticide consumption countries [14].

Globally, Asia uses more than half of all pesticides. India is third in Asia, following China and Turkey, in terms of overall pesticide usage. Lack of awareness amongst the farmers is the major cause of increased agrochemical usage in India. A per

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FICCI 2019 report on agrochemical usage, it concluded that out of all used agrochemicals in India, insecticides usage is 60% which is highest followed by fungicides 18%, herbicides 16% and others (used for crop storage) are 6%. [16] In India out of 293 registered pesticides, out of these 104 are still being used even after the prohibition by Government of India. These insecticides have systemic impact on the plants. As these are absorbed by the plant tissues leading to long term residual impact on the plant tissues and are then ultimately consumed by humans. Rapid urbanization has led to increased demand and shift towards nutritious or healthy diet i.e., fruits & vegetables. This production is likely to increase from 268 million tonnes to 647 million tonnes by 2050. This will be approximately two and half times more than the current consumption [17]. Therefore, pesticide usage will increase to meet the increased demand and decrease loss in fruits and vegetables. More than 70% of the agrochemicals used in India are used in eight states: Andhra Pradesh, Maharashtra, Punjab, Madhya Pradesh, Chhattisgarh, Gujarat, Tamil Nadu, and Haryana [16].

Various studies showed that India uses comparatively lesser number of pesticides per hectare area, but uncontrolled, injudicious and haphazard usage of pesticide is leading to increased pesticide residues in environment as per the percent usage [13].

Evidence of impact of chemical toxicity on human health

At global level:

A number of pesticides have been linked to adverse effects on human health and the environment. These insecticides can be ingested, inhaled, or come into contact with the skin. The type of pesticide, the length of exposure, the method of exposure, and the individual health status (such as dietary deficits and the condition of one's skin, for example) all affect the potential health outcome [18]. Chemical pesticides have been linked to a wide range of unfavourable health consequences, including impacts on the skin, gastrointestinal system, nervous system, respiratory system, reproductive system, and endocrine system [19,20,21]. High levels of occupational, unintentional, or purposeful pesticide exposure can also cause illness and even death [22].

The different categories of chemical toxicity occur through use of different pesticides such as use of OCPs is associated with health impact and occurrence of endocrine disorders, embryonic developmental disorders, haematological and hepatic changes, as well as lipid metabolism [23-27]. Evidence from various population specific studies showed the possible link between exposure to organophosphorus pesticides and adverse health effect. These includes CVDs, ill effect on male reproductive system, nervous system, dementia, raised risk for non-Hodgkin's lymphoma with decreased gestational period and nervous system problems occurring in children [26,28].

Although there is evidence that pesticide application can significantly reduce or offset the economic costs associated with weeds, insect pests, and plant diseases on agricultural production. Also, fertilizer application can provide a variety of essential nutrients necessary for crop growth and for higher yields [29]. However, fretting amounts of agricultural chemical residues have been found in soil, water, air, crop residues, human blood, and adipose tissue, among other places [13].

Evidence indicates the widespread consumption of chemical or artificial fertilizers contributes to the buildup of pollutants in agricultural soils, such as arsenic (As), cadmium (Cd), fluorine (F), lead (Pb), and mercury (Hg) [30]. There have been claims that growing usage of agricultural chemicals has negative environmental effects that have contaminated drinking water and leached into the groundwater [31]. Short-term or long-term health impacts from exposure to agricultural pesticides are being reported by farmers in developing nations. These effects include severe symptoms (such as headaches, allergic reactions to the skin, and eye irritation) and some chronic impacts (such as cancer, endocrine disruptions, and birth defect).

It has been notified that the agrochemicals and other chemical fertilizers or products which are used to increase the productivity of the soil fertility and crop production are majorally lipid soluble compounds and are capable of bioaccumulating in the fatty parts such as breast milk, blood and fatty tissues [32]. Because these pesticides are highly hazardous to both aquatic life in and humans, this impact is through micropollutant exposure by consuming crops that have come into contact with pesticide contaminated soil or water.

At National level:

The links between the human health and usage of agrochemical were suspected from the past and the link for the same has been developed in India by various epidemiological studies. A study done in the Northern Indian population with a focus on water sample (including effluents, ground and surface), fodder, vegetables, milk (bovine & human) and biological samples (blood & urine) showed that in the areas with heavy metal contamination, persons are suffering from gastro-intestinal, water related, eye, dermal and bone related disorders. Variety of heavy metals (Mercury, lead, chromium, cadmium and selenium) were detected in more than permissible limits (MPL) both in water sources including ground & surface water. The high prevalence of micronuclei was also detected [33]. Evidence suggests that the MPL is of various pesticides are far high in the ground water and effluent samples and These pesticides includes Chlorpyriphos, β-endosulphan, dimethoate, heptachlor and α-endosulphan. These pesticides including the traces of heavy metals were detected in vegetables, fodder, milk, urine

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and blood samples also. A significantly high systemic and general health effects including the evidence of genotoxic effect manifests the heavy metal and pesticide contamination of water sources [33].

A study on the reproductive and child health outcomes in the state of Punjab showed the higher rates of spontaneous abortion (20.6 per 1000 live births) and premature births (6.7 per 1000 live births) in heavy metal and pesticide polluted areas. The peculiar finding was that the stillbirths were 5 times higher in comparison to other South Asian countries. The impact includes slowed milestones, speech delay, blue gum line, tooth mottling and gastrointestinal disorders. The probable reason was the higher levels of mercury in that paticular area. Heptachlor, chlorpyriphos, b-endosulphan, dimethoate and aldrin were detected more than MPL i.e., 23.9%, 21.7%, 19.6%, 6.5% and 6.5% ground water samples respectively [34]. Another study showed the presence of malathion, dieldrin and y-HCH in ground water of Ganges [35]. Regarding the higher cancer prevalence in Punjab, in an epidemiological study site wise distribution showed that the cancer of female reproductive system, i.e., breast, uterus/cervix and ovary were more common in one district as compared to the other district where the cancer of blood and lymphatic system, oesophagus, and bones were more common. Detailed comparison revealed the link of cancer case or death with the involvement in agriculture, pesticide use, alcohol use and smoking. However, higher levels of of heavy metals such as, Cd, Cr, Se, Hg and pesticides such as heptachlor, ethion, and chlorpyrifos were significantly higher in samples of drinking water, vegetables, and blood in area with higher cancer. There is evidence that the soil is accumulating pesticides and heavy metals leading to adverse impact on soil health [36,37]. Table 1 details about the presence of various pesticide residues in the Ground water, Vegetables and fodder, human blood, milk and bovine milk[35-39]. There are various metabolites also which detected in the human urine samples also. Various epidemiological studies conducted to estimate the heavy metals showed that the maximum percentage of groundwater samples of Malwa region is beyond the permissible limits and that's why the water is not fit for drinking purposes and other domestic activities. In the groundwater samples of Punjab Arsenic, lead, Iron, Cobalt, Chromium, zinc and Mercury are also detected. Not only in the ground water but the heavy metals are also detected in the cultivated land, vegetables and human body[37-39]. The details of the heavy metals in these are mentioned in the Table 2.

The utilization of agrochemicals in the form of spraying or chemical fertilizers poses a great impact on soil in terms of accumulation of heavy metals in to it. A Southern Indian study revealed that the higher concentration of the heavy metals differs in the plant part as well such that heavy metals get accumulated in different parts of paddy plant (Oryza sativa L.) including the grains such as Mn and Cd are found to be accumulated more in shoot than in root. The metal transfer factors from soil to rice plant were significant for Pb, Cd, Cu, Cr, Mn, and Zn. The ranking order of biomagnification in human body (BAF) for heavy metals was Zn > Mn > Cd > Cu

Table 1: Pesticide residues detected in Ground water, vegetables, humans and animals in Punjab (Reference year 2003-2023)

Ground water	Vegetable	Human Blood	Human Milk	Bovine Milk
• Chlorpyriphos	• Chloropyrifos	• Chloropyrifos	• Chlorpyriphos	• Chlorpyriphos
• βendosulphan	• α-endosulfan	• β-endosulfan	• β-endosulphan	• β-endosulphan
• αendosulphan	• Heptachlor	• Heptachlor	• Heptachlor	• Heptachlor
• Heptachlor	• γ- HCH	• α-HCH &	• α-HCH	• α-HCH
• Hexachloro- cyclohexane (HCH)	• Endoepoxide	• β-HCH	• 4,4-DDE	• 4 DDE
• DDT	• Ethion	• Dichlorodipheny l		• Aldrin
• Dimethoate		• dichloroethylene (DDE)		
		• Aldrin		
		• Monocrotophos		
		• Profenophos		
		• Phosalone		
		• Methyl parathion		
		• Quinalphos		
		• Malathion		

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> Cr > Pb indicating that the accumulation of micronutrients was more than that of nonessential toxic heavy metals. The lead ingestion through the grain of the rice is leading ill effects on human [40]. The studies mentioning about the of impact of use of pesticides or agrochemicals on human health and various systems are mentioned in Table 3.

Table 2: Heavy metals detected in Ground water, vegetables and humans in Punjab (Reference year 2003-2023)

Ground water	Vegetable	Human Urine	Cultivated land
• Selenium	• Selenium	• Selenium	• Copper
• Zinc	• Zinc	• Copper	• Zinc
• Lead	• Lead	• lead	
• Cadmium	• Cadmium	• cadmium	
• Uranium	• Uranium	• Arsenic	
• Nickel	• Nickel	• Nickel	
• Chromium	• Chromium	• Mercury	
• Manganese	• Manganese		
• Mercury			
• Fluoride			
• Magnesium			
• Antimony			

Table 3: Impact of use of pesticides or agrochemicals on human health and various systems

Reproductive system	
Birth Weight [41]	· Birth outcomes (birth weight, head circumference, infant's length, and ponderal index) revealed a significant and positive association with the levels of Acetylcholinesterase activity in maternal blood, placenta, and cord blood in TGW ($p < .05$).
	· Substantial decrease of 5.81, 1.94, 4.71, and 2.64 g of birth weight for 1 ppb (µg/L) increase in placental α-HCH, β-HCH, γ-HCH, and total HCH concentrations respectively.
	· Significant decrease of 2.02 and 0.43 kg/m3 in ponderal index was found with 1 µg/L increase of total-HCH and total DDT concentrations in placenta.
Spontaneous abortion [42, 43]	· A higher level of pesticide, namely beta-hexachlorocyclohexane, malathion, chlorpyrifos, and pyrethroids significantly impacts the abortion prevalence ($P < 0.05$).
	· Spontaneous abortion (20.6 per 1000 live births) and premature births (6.7 per 1000 live births) were significantly higher in area affected by heavy metal and pesticide pollution.
Pre term delivery [41, 44,45]	· The mean levels of pesticide (α-HCH, total-HCH, p,p-DDE and total-DDT) were found statistically significant and associated with pre term delivery .
	· Pesticide exposed women were approximately 1.7 times more likely to deliver pre-term baby as compare to pregnant women that were not exposed to any pesticides.
	· There were significant positive correlations of placental pesticide (α-HCH, γ- HCH & total HCH) levels with malondialdehyde ($p < 0.05$), suggesting that pre- term delivery is pesticide-induced.
Neurodevelopment and neurobehavioral effects [46,47]	
Neurological symptoms [46,47]	· Adverse health effects in farm workers including tingling (32.3%), muscle pain (51.6%), headache (56.5%), skin disease (19%), blurred vision (35.5%), tremor (23%), stress (24.2%), depression (15.3%), anxiety (44.7%), altered taste (21.4%), altered smell (31.4%), sleep disorder (39.5%), dizziness (66.1%), memory problems (29.4%), trouble in walking (8%), and cardiac problems (16.9%) were reported
Depressive symptoms [47]	· A significant increase in depressive symptoms in pesticide exposed workers as compared to the unexposed.
	· A decrease in the level of dopamine in plasma and levels of dopamine, 3,4□dihydroxyphenylacetic acid, homovanillic acids, norepinephrine, serotonin, and hydroxyindoleacetic acid in urine in exposed as compared to non-exposed.
Neural tube defects [45]	· The median blood levels of DDE, t-HCH and endosulphan in mothers can lead to neonates with NTDs.
Respiratory adverse effects	
Peak expiratory flow rate [48]	· There was a significant decrease in PEFR among the farmers ($p<0.001$) compared to the controls.
	· Pesticide sprayers also had significantly lower mean peak expiratory low rates and poor peripheral sensations.

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Other Respiratory symptoms [48]	The pesticide sprayers had **higher prevalence of breathlessness** on activities of daily living (odds ratio [OR]: 3.14, 95% confidence interval [CI]: 1.22-8.07),
	Chronic cough/phlegm (OR: 3.53, 95% CI: 1.09-11.46), symptoms of peripheral sensory neuropathy (OR: 6.66, 95% CI: 2.53-17.51) and
Cancer as an outcome	
Ovarian cancer [49]	Significantly high levels of beta-hexachlorocyclohexane (β-HCH), endosulfan-I, endosulfan-II, dichlorodiphenyltrichloroethane (p'p'-DDT), dichlorodiphenyldichloroethylene (p'p'-DDE) were observed in cases as compared to controls.
Breast Cancer [50,51]	Endosulfan-II, p,p'-DDT, and p,p'-DDD tissue levels are significantly higher in breast cancer patients than in those with fibroadenoma.
	Young women with breast cancer were found to have significantly higher serum levels of all the OC compounds except aldrin, p, p' DDT, and methoxychlor.
Prostatic hyperplasia [52]	Higher level of pesticide namely beta-hexachlorocyclohexane (β-HCH), Malathion, Chlorpyrifos and Fenvalerate were found in PCa group (all p value: < 0.05).

Overall impact on the ecological system

From the review of the exiting evidence, it has been established that agricultural soil is the primary recipient of agrochemicals usage, but it ultimately impacts the food chain who consume those products leads to biomagnification of various chemicals and heavy metals. The water bodies adjacent to these agricultural areas are usually the ultimate recipient for agrochemical residues. There is a evidence that agrochemicals residues are common in the surface water system, especially in irrigation drains, which ultimately pollute the ground water, ponds and the aquatic life. The figure 1 depicts the impact of agrochemical usage on human and soil health. The summary of the outcome of the ecological crisis from varies studies is given in figure 1.

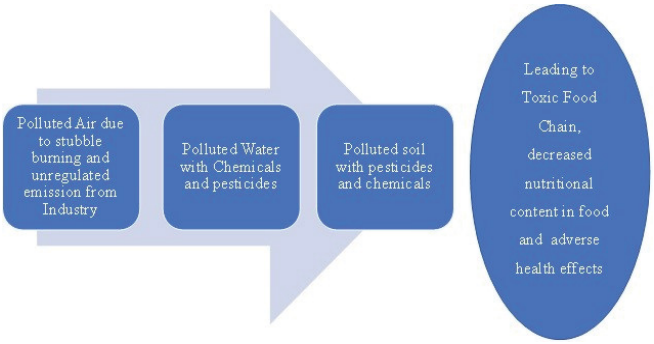

Figure 1: Case Study of outcome of the ecological crisis in Punjab state

Discussion

Soil contamination is the result of human activity, high use of pesticides, untreated industrial effluent and agricultural runoff including the entry of industrial wastes into soil through atmospheric deposition or application of agrochemicals and untreated municipal waste to the land. These organic contaminants reduce the soil quality for agricultural production. Soils are very important in the fate and distribution of persistent toxic substances in the environment since they have a huge retention capacity and they may work as re-emission sources for the atmosphere [53]. In view of the common practice of application of untreated wastewater to agricultural land in the neighbouring area should be strictly prohibited as the pollutants might enter into the food chain and cause health hazards to humans. Injudicious use of pesticides and other persistent organic pollutants in agricultural soils have devastated future repercussions [13]. The persistent and ubiquitous nature of various agriculture-based pesticides and other organic pollutants has posed havoc to the mankind due to their bioaccumulation properties and high toxicity [54]. These pesticides are known to hinder the normal functioning of endocrine and reproductive systems in living organisms [34]. There may be other alternatives available to control crop loss due to pest attack which may include the application of various biopesticides. In India, the bio-pesticide consumption only accounts for 9% approximately of overall pesticide usage [55]. Developing some pest-resistant crop varieties using various approaches is also one method to avoid pesticide use [56]. But application of chemical pesticides is still preferred the most over all other alternatives to protect crops from yield loss. Pesticides are applied to increase crop productivity; however, in due course of time, they get accumulated in plant parts, water, soil, air and biota. Extensive use of pesticides contaminates soil and water, remain in the crops and finally enter food chain, thereby posing threat to the human beings. The commercial use of pesticides in agriculture produces vapours of pesticides that have the ability to become air pollutant. Pesticides used in agriculture are synthetic in origin and get absorbed in the soil through surface runoff from treated plants [31,38]. The deposition of organic chemicals or pesticides in soil directly exposes soil organisms and also increases the risk for other higher organisms through diet and can severely affect soil ecosystem, water bodies, plants and human health [33,35]. Keeping in mind the extensive use of pesticides throughout the globe, the present review gives an overview about the application of pesticides in the world and their various impacts on the ecosystem.

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Since chemical fertilizers and pesticides are indiscriminately used by Indian farmers, which are probably the main sources of the toxic heavy metals accumulated in the paddy fields as well as other crops as well [16]. Organic agriculture with little use of agrochemicals could be the alternative solution for reducing the contamination of toxic heavy metals [57]. The agrochemical usage and productivity curve, the classic curve shows that the productivity increases with the increasing investment in agrochemical usage per hectare [58]. Contrary to this the reality curve shows that productivity declines with the over usage of fertiliser. Overall, this will lead to diminution of returns i.e., in terms of extra expenses, soil and water pollution and decreased crop output [58].

The issue of the soil health can be addressed by various ways such as linking of soil security to human health, innovative farming methods such as Natueco Farming(natural and ecological farming), promotion of food safety and food security [59-61]. An important component in all is the action relation to the Multisectoral and intersectoral coordination [62]. Natueco farming is a newer concept based on the usage of innovative methods for enriching soil and water. This method ensures sustainable supply of nutrients in the soil by using minimum external inputs and maximizing utilization of neighbourhood resources. Natueco Farming, a pro-biotic farming system, has shown promising results and its produce have been found to contain all nutrients higher including vitaminB12 as compared to traditional farming. This enriched soil called Amrut Mitti (enriched soil) and enriched water Amrut Jal (enriched water) is a panacea for all health problems of Humanity. It aims to shift entire narrative of agriculture from productivity to nutrivity and eventually to health and wellness through collective consciousness [60]. Concept of Community farming can be promoted so as to shift the pesticide usage practices to the bio or organic farming [63].

Food safety is an important component to deal with the concept of soil health as it covers Safety from known (chemical or biological) substances that lead to known (or unknown) illness or death (botulism, pesticides, cholera); Safety from long-term chronic diseases related to quality of diets (diabetes, heart disease) and Safety from deliberate contamination anywhere along the supply chain of an otherwise safe food supply (bio or chemical terrorism) [59].

The decisions or initiatives taken at National level includes National Mission on Sustainable Agriculture, National Multisectoral action plan 2015-2022 emphasized on partnership framework and inclusion of key ministries with a single objective, District health promotion model developed in Punjab and Haryana state and FSSAI: EAT Right India initiative [64].

Policymakers recognize that the excessive and unsystematic application of agrichemical inputs, pesticides and fertilizers in particular, is an obstacle to the development of sustainable agriculture, and poses a threat to the environment and humans alike. The decisions need to be taken at policy level should focus to build and maintain adequate food systems and infrastructures (e.g. laboratories) to respond to and manage food safety risks along the entire food chain, including during emergencies; foster multi-sectoral collaboration among public health, animal health, agriculture and other sectors for better communication and joint action; integrate food safety into broader food policies and programmes (e.g. nutrition and food security); and think globally and act locally to ensure the food produce domestically be safe internationally [65]. The key recommendations after the review of the exiting literature includes that the development of sustainable policies: Mechanisms of monitoring and evaluation of pesticide availability and usage; Inclusion of the concept of sustainable agriculture, agricultural practices and One Health in Education curriculum (school, college, university); promotion of crop diversification, provision of subsidies for the same as well as evidence-based Agriculture Guide availability for the information of farmers on crop diversification; strategies like Taxation and Information broadcasting may be adopted to regulate the use of insecticides/pesticides; Research priorities should focus on the models of sustainable agriculture, Organic farming, Setting up, expansion and strengthening the agricultural laboratories; Incentivizing or subsidies to the farmer groups or farmers for adopting the healthy and sustainable agriculture practices; and FPOs and civil society organizations investing in sustainable agricultural practices may be accredited to be trainers for more farmer groups [66].

Conclusion

Soil has a considerable effect on human health, whether those effects are positive or negative, direct or indirect. However, nutrient imbalances and the presence of human pathogens in the soil biological community can cause negative effects on health but the injudicious use of agrochemicals is creating major impact on the human health and ultimately to the whole ecosystem. Concepts such as soil security provides a framework within which issues on soil and human health can be investigated using interdisciplinary and transdisciplinary approaches i.e. Multisectoral approach. The innovative methods such as organic farming, Natueco farming are the future to reduce the chemical toxicity. It will take the contributions of experts in several different scientific, medical and social science fields to address fully soil and human health issues. There is a need for regular epidemiological surveillance for soil and water quality, strengthening measurements by developing point of care technologies, clinical studies and sustained prevention and control efforts for addressing chemical toxicity and its health effects.

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Declarations

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Study concepts: JST

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Manuscript editing: JST., RP

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CRediT authorship contribution statement:

JS Thakur: Conceptualization, Supervision, Writing - review & editing;& Ronika Paika: Data curation, Formal analysis, Visualization, Writing - original draft, Writing - review & editing;

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