International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 7.328
Peer Reviewed Bi-Monthly
Vol.11 No.3 January – February 2024

The Human Health Impacts Of Pesticides: Understanding Exposure, Risks, And Long-Term Effects

Dr. Ishfaq Majeed Malik

Ph. D. in Environmental Science
Department of Environmental Science, Jammu and Kashmir, India
Corresponding Author - Dr. Ishfaq Majeed Malik

DOI - 10.5281/zenodo.10718939

Abstract:

Pesticides are broadly utilized in agrarian creation to limit or totally kill yield misfortunes while keeping up with great item quality, as well as to forestall or oversee illnesses, weeds, bothers, and other plant microorganisms. Despite the fact that pesticides go through unquestionably rigid The requirement for administrative systems to work with sensible certainty and negligibly affect human wellbeing and the climate has become obvious considering the wellbeing gambles related with word related openness as well as buildups in food and drinking water. Rural specialists in open fields and nurseries, exterminators of family vermin, and those utilized in the pesticide business are frequently presented to pesticides at work. Pesticide deposits in food and water are the fundamental ways that the overall population is presented to pesticides, however significant openness can likewise happen inside or near homes. The hurtfulness of the pesticide, the security gauges taken during application, the portion, the adsorption on soil colloids, the environment that occurs after application, and how long the pesticide stays in the environment are factors that impact the hostile effects on untamed life, fish, plants, and other non-target natural elements as well as the threatening ramifications for the environment (contamination of water, soil, and air due to depleting, overflow, and shower float).Concerns in regards to pesticides' likely impacts on human wellbeing continue in spite of the way that involving them in agribusiness has become vital for current cultivating rehearses. An overview of the complex interaction between pesticides and human health is given in this abstract, with a focus on the significance of comprehending exposure, evaluating risks, and determining long-term impacts.

Keywords: Human Health, Pesticide, Exposure, Risks, Long-Term

Introduction:

In addition to the extensive use of pesticides to protect crops from pests and guarantee that food production worldwide satisfies the demands of a growing population, modern agriculture has experienced a fundamental transformation. [1] Despite the fact that these chemical interventions have been crucial in raising agricultural output, worries regarding their possible effects on human health have surfaced. Because pesticides are made to tackle a wide range of agricultural hazards, people may unintentionally come into contact with these substances through eating contaminated food, breathing in, or coming into contact with them on their skin while the pesticide is being applied. The complex interrelationship between pesticide usage and human health outcomes demands a thorough investigation of the subtleties of exposure, related hazards, and potential long-term consequences. Determining the health effects of pesticides requires first understanding the paths of exposure. [2] The ingestion of food items treated with pesticides presents a direct and immediate pathway for pesticide exposure into the human body. Exposure can also result via inhaling pesticide particles during application or drift, especially for people who live close to agricultural regions. Agricultural workers are also exposed to pesticides through skin contact when handling and applying them. The intricacy of determining and reducing the health effects of pesticides on a range of people is highlighted by the variation in exposure pathways.

Evaluating the dangers of pesticide exposure requires careful evaluation of a variety of factors. Acute toxicity is a known risk that frequently presents as instantaneous negative effects. On the other hand, a more subtle problem arises from the long-term cumulative effects of repeated exposure to lower pesticide doses. Studies using epidemiological methods have connected pesticide exposure to a number of health problems, such as neurological conditions, problems with reproduction, and specific types of cancer. [3] Pregnant women and children in particular may be particularly vulnerable to these dangers, which highlights the need for a more comprehensive knowledge of the variables influencing unfavourable health outcomes. In addition, the possible long-term consequences of pesticide exposure give rise to worries about the possible development of chronic diseases. This problem is made more complicated by the persistence of some pesticides in the environment and their capacity to bioaccumulate in the food chain. Therefore, a comprehensive analysis of the chemical characteristics of pesticides, their interactions in ecosystems, and their cumulative effects on human health is necessary to decipher the complex network of relationships between pesticide exposure and the development of chronic health disorders. This paper aims to give a thorough summary of the effects of pesticides on human health in light of these factors. Our goal is to contribute to a comprehensive understanding of the complex relationship between agricultural practices and public health by delving into the details of exposure pathways, assessing associated risks, and comprehending potential long-term repercussions. By doing this, we hope to contribute to the development of public policies, agricultural practices, and future research initiatives that put the needs of the world's population and food security first.

Review of Literature:

An extensive summary of the consequences pesticide residues has on the environment and human health is given by Ali and associates (2021). The review examines a range of pesticides, including their distribution, modes of action, and possible threats to human health and ecosystems. [5] The paper promotes the use of strong analytical techniques to track and evaluate the effects of pesticide exposure and stresses the significance of comprehending the complexity of pesticide exposure.

Benbrook and his co-authors (2021) add to the body of literature by putting forth cutting-edge tactics and equipment to lessen the negative impacts of pesticides on human health. The essay highlights the need for a paradigm shift in pesticide management by outlining the shortcomings of the current methods and offering creative solutions. [6] In order to provide more practical and long-lasting solutions, the authors support a comprehensive strategy that takes ecological, epidemiological, and toxicological aspects into account.

Boonupara et al. (2023) concentrate on chemicals that are released into the air as a result of agricultural operations. Their rigorous analysis looks at the different ways that pesticides can enter the air, the elements that can spread them, and the possible health effects on people. [7] The paper emphasizes how crucial it is to comprehend the dynamics of pesticides in the air in order to effectively assess and manage risk.

Brhich and associates explore the effects and destiny of pesticides in 2022, providing a thorough examination in the larger framework of human nutrition and health. The chapter delves into the environmental and public health concerns related to pesticide use, illuminating the complex processes by which these substances interact with ecosystems and may have an impact on human health. [8] The fact that nutritional factors are included emphasizes how closely agricultural practices and public health are related.

An extensive analysis of the connection between agrochemicals, the environment, and human health is given by Devi, Manjula, and Bhavani (2022). Their paper, which was published in the Annual Review of ecosystem and Resources, critically analyses how pesticides and other agrochemicals affect both human health and the ecosystem. [9] The evaluation covers topics like soil erosion, water source contamination, and possible health concerns from extended exposure to pesticide residues.

Human Exposure to Pesticides and Factors Affecting Exposure:

Among the sorts of people who might be occupationally presented to pesticides incorporate the individuals who work in the pesticide business, exterminators of family bugs, and farming laborers in nurseries and open fields. Whether or not making a difference pesticide is expected for the undertaking, there is a risk of word related openness when they are available in the work environment. Laborers who handle, blend, burden, transport, and apply formed pesticides are frequently accepted to be the most uncovered and, subsequently, generally vulnerable to intense inebriations because of their temperament of work. Synthetic spills, spills, or broken shower gear can once in a while open people to pesticides.[10] At the point when laborers don't follow utilization proposals, they are bound to be presented to pesticides. This is particularly obvious when laborers don't follow essential wellbeing conventions like wearing PPE and cleaning up prior to eating or subsequent to dealing with pesticides. Openness during the treatment of pesticides can change in light of a few conditions. The definition of pesticide items could influence the level of openness. Spills and sprinkling are successive events with fluids, and they can bring about apparel tainting or direct skin contact. At the point when solids are placed into the application device, they might create dust, which represents a gamble to respiratory wellbeing and eye and facial openness. The kind of bundling utilized for pesticide items is another component affecting likely openness. For instance, opening pesticide sacks might open one to changing degrees of defilement relying upon the holder type and definition of the dynamic fixing. The size of jars, bottles, and other fluid holders may likewise influence how probably spills and sprinkles are.

Adjuvant synthetic substances can be poisonous, which could build the general effect of openness to a business pesticide item. Adjuvant synthetic substances are added to pesticide details to work on organic action (i.e., to work on the contact between the dynamic fixing and its specific sub-atomic objective), work with application, and arrive at target species. Dampness and air temperature during application can influence an individual's pace of perspiring, the synthetic instability of the item, and whether they wear individual insurance hardware [36, 38-40]. How much splash float and the utensil's resulting openness are significantly expanded by wind. Since more noteworthy breeze builds how much pesticide lost from the objective district and the distance it goes, higher breeze speeds typically incite more float. Besides, in low relative stickiness and high temperature settings rather than high relative dampness and low temperature circumstances, splash beads will dissipate between the shower spout and the objective all the more rapidly.

Openness can likewise be significantly impacted by the overall cleanliness rehearses utilized by staff while using pesticides. [11] One way that specialists could lessen their openness is to not blend or splash when it's blustery outside. Proper wear and support of defensive stuff is viewed as a significant way of behaving related with lower openness to synthetic compounds. Moreover, the length and recurrence of dealing with pesticides both all year and during explicit seasons influence openness. In particular, a singular rancher applying a pesticide once a year will be presented to less of it than a business implement who regularly applies it for a few successive days or weeks over a season. However there are alternate ways of being seriously presented to pesticides, for example, residing near an organization that utilizes them or in any event, while laborers bring sullied objects home, the overall population is transcendently presented to pesticides through eating contaminated food and drinking dirtied water. Low measurements are regularly associated with persistent (or semi-constant) non-word related openness to pesticide deposits in food, air, and drinking water. Be that as it may, concentrates on led on creatures are the main method for laying out an immediate connection between a particular pesticide and its effect on human wellbeing; notwithstanding, the amounts of pesticides utilized in these examinations are far higher than those allowed by regulation. Consequently, it seems impossible that these examinations will adversely affect individuals' wellbeing. Nonetheless, the genuine intense openness might be higher than anticipated because of individual dietary inclinations, remaining heterogeneity among individual food things, and greater than normal utilization of a specific food thing in a solitary sitting. During the readiness, application, and, surprisingly, after the medicines are finished, anybody who use pesticides in or around the house might come into contact with them. On the other hand, deferred openness can happen when an individual takes in leftover air focuses or comes into contact with buildups on objects, garments, bedding, food, dust, deserted pesticide holders, or application devices.

Pesticide and Human Health:

The most common way of evaluating the gamble that pesticides posture to human wellbeing isn't basic or especially exact because of different factors, for example, openness levels and periods, poisonousness of pesticides, field blends or mixed drinks, and the geological and meteorological qualities of horticultural regions where pesticides are utilized. Individuals who produce the mixes in the field, the pesticide sprayers, and the local individuals who live close to the sprinkled districts, pesticide storerooms, nurseries, or open fields are the chief subjects of these changes. In this manner, a higher bet is supposed to result from high receptiveness to an honorably noxious pesticide than from little receptiveness to an especially destructive pesticide, taking into account that the gamble to human prosperity is a part of pesticide hurtfulness and transparency. [12] There is still a ton of conversation in science on the potential prosperity bets related with the general populace's dietary receptiveness to pesticide stores found in food and drinking water.

Despite the difficulties in assessing the wellbeing gambles related with pesticide utilization, proof about conceivable unfavorable impacts of the dynamic fixings on human wellbeing are presently required for pesticide commercialization in Europe to be approved. Generally, various tests are led to assemble this information. These tests might zero in on digestion designs, intense poisonousness, sub-constant or sub-intense harmfulness, persistent poisonousness, cancer-causing nature, genotoxicity, teratogenicity, age review, or bothering preliminaries with rodents filling in as model warm blooded animals, or sporadically on canines and bunnies. The different poisonous quality tests for human thriving gamble evaluations expected by

EPA are (1) the outrageous perniciousness test, which concentrates on the impacts of passing responsiveness to a solitary piece of pesticide (oral, dermal, and inside breath straightforwardness, eye disturbing, skin exacerbation, skin refinement, neurotoxicity), (2) the sub-advancing toxicity test, which audits the impacts of halfway rehashed openness (oral, dermal, interior breath, nerve system hurt) all through an all the more lengthy timespan range (30-90 days), (3) the resolute destructiveness test, which outlines the impacts of extended length emphasized responsiveness occurring for by a long shot a large portion of the guinea pig's future and needed to finish up the impacts of a pesticide thing after conceded and rehashed openings (e.g., consistent non-disease and disorder impacts), (4) the formative and regenerative tests, which evaluate any most likely impacts in the lacking living being of a revealed pregnant female (i.e., birth twists) and what pesticide straightforwardness could mean for the restriction of a guinea pig to duplicate effectively, The five tests are the mutagenicity test, which studies a pesticide's capacity to change a phone's hereditary parts, and the compound impedance test, which gauges a pesticide's capacity to thwart the endocrine system, which is contained organs and the engineered materials they produce, which control a creature's new development, improvement, expansion, and lead, including human way to deal with acting. [13] The center lethal estimation (LD50), or the pesticide segment expected to kill half of the attempted animals when it enters the body through a particular course, not completely firmly established by the serious noxiousness studies. For example, the figure addresses the oral LD50 assuming the substance is taken, and the dermal LD50 in the event that it is assimilated through the skin. Moreover, the pesticide portion expected to kill half of the tried creatures presented to it for four hours is known as the intense inward breath deadly fixation, or LC50. At the point when the technique for organization is by drinking water or inward breath (instead of oral, cutaneous, and so on), deadly fixation values are utilized. The pesticide harmfulness groupings utilized by the EPA and What which's identity is, showed in Tables 1 and 2.

Table 1: Pesticides' acute toxicity based on WHO classification

Class	Hazard Category	Oral Solids (mg/kg b.w.)	Dermal Solids (mg/kg b.w.)	Oral Liquids (mg/kg b.w.)	Dermal Liquids (mg/kg b.w.)
Ia	Extremely hazardous	<6	<30	<20	<52
Ib	Highly hazardous	6–62	30–320	20–200	53–500
II	Moderately hazardous	63–601	320–3,000	200–2,001	500–5,000
III	Slightly hazardous	>605	>3,001	>2,001	>5,001
U	Unlikely to present acute hazard	>3,001	>4,000	>2,000	>5,000

The table's hazard classification system provides an essential foundation for assessing the possible risks associated with compounds according to their toxicity when exposed through different pathways. Class Ia, which designates compounds as extremely dangerous, is the highest risk category. Because oral and dermal solid dosages are less than 6 mg/kg and 30 mg/kg body weight, respectively, considerable precautions are required. Class Ib, which is made up of extremely dangerous drugs, has somewhat higher dose ranges but still needs close regulatory supervision. Class II includes compounds that are moderately dangerous and have broader dose ranges than the previous classes. Class III, on the other hand, includes drugs that are somewhat hazardous and have lower acute hazards but still require attention. Class U compounds have greater dosage thresholds, indicating a lower immediate risk, indicating that they are unlikely to create acute dangers. In order to ensure the efficient management and reduction of potential health dangers connected with various chemical agents, regulatory choices are guided by this systematic classification, which makes it easier to grasp the toxicity of substances.

Table 2: Acute toxicity of pesticides as classified by the EPA

Class	Signal Words	Acute Toxicity to Rat (Oral LD50 mg/kg)	Acute Toxicity to Rat (Dermal LD50 mg/kg)	Acute Toxicity to Rat (Inhalation LC50 mg/L)
I	DANGER	<60	<300	<0.5
II	WARNING	60–600	300–4,000	0.6–3.5
III	CAUTION	600–6,001	3,000–40,000	3.5-30
IV	CAUTION (optional)	>6,001	>40,000	>40

Through the incorporation of oral, cutaneous, and inhalation exposure routes, the classification system shown in the table offers a thorough framework for conveying the acute toxicity of chemicals based on their effects on rats. Class I materials have the highest acute toxicity level and are denoted by the signal word "DANGER." These drugs have LD50 values in the oral range of less than 60 mg/kg, the dermal range of less than 300 mg/kg, and the inhalation range of less than 0.5 mg/L. Substances with considerable acute toxicity are classified as Class II, denoted by the signal word "WARNING," and have oral dosage ranges of 60 to 600 mg/kg, cutaneous dose ranges of 300 to 4,000 mg/kg, and inhalation LC50 values of 0.6 to 3.5 mg/L. With oral LD50 values between 600 and 6,001 mg/kg, dermal LD50 values between 3,000 and 40,000 mg/kg, and inhalation LC50 values between 3.5 and 30 mg/L, Class III, indicated by the signal word "CAUTION," comprises compounds with reduced acute toxicity. Class IV compounds have the lowest acute toxicity; their oral LD50 values exceed 6,001 mg/kg, their dermal LD50 values exceed 40,000 mg/kg, and their inhalation LC50 values exceed 40 mg/L. Class IV is also labelled as "CAUTION" (optional). [14] In addition to signal words, this systematic classification is a useful tool for communicating possible dangers and directing necessary safety measures based on acute toxicity levels across various exposure paths.

Pesticide and the Environment:

Apart from their possible harm to human health, pesticides can also have detrimental impacts on the environment, such as contaminating water, soil, and air, or poisoning creatures that are not their intended targets.

Specifically, not recommended pesticide use has been connected with: (1) unfavorable outcomes on non-target natural elements (e.g., diminishes in peoples of profitable species); (2) pesticide-related water debasement; (3) pesticide-related air tainting; (4) wickedness to non-target plants from herbicide float; (5) naughtiness to rotational harvests from herbicide developments left in the field; and (6) crop hurt as a result of extravagant application rates, improper application timing, or terrible biological conditions

The collaborations between the pesticide's physicochemical properties (rage pressure, robustness, dissolvability, and pKa), soil adsorption and unfaltering quality, soil factors (pH, regular parts, inorganic surfaces, soil sogginess, soil microflora, and soil fauna), plant species, and climate assortment address innumerable the antagonistic results of pesticides on the environment. The pesticide's destructive consequences for the climate may likewise be made sense of by its poisonousness, the measurements utilized, the climate that exists after the pesticide is splashed, and the timeframe it stays in the climate.

It has for some time been recognized that dirt qualities and meteorological variables significantly affect how a pesticide winds up in the climate and, thusly, on its movement, selectivity, and hurtful consequences for the ecosystem. Tragically, the results of any field examination on the destiny and conduct of the pesticide are restricted to a solitary region and season in light of the fact that these factors vary from one site to another and from one year to another. The way of behaving and destiny of a pesticide are subsequently first assessed for the ecological gamble evaluation by computing the expected natural focus (PEC), otherwise called the assessed ecological fixation (EEC) in the US .

The approval interaction includes looking at the anticipated fixations for soil, water, silt, and air with the information accumulated from the three testing levels (expected for endorsement enlistment purposes) to decide the poisonousness of pesticides on significant non-target creatures (Table 4). To discover assuming the gamble to the organic entity is OK or not, the poisonousness openness proportion (TER) is additionally registered . The LC50 or identical measure (LD50, NOEC = no recognizable impact grouping) of a creature's defenselessness separated by the PEC appropriate to the climate where the life form is residing is the manner by which TER is figured.

Table 3: The trio of tests to evaluate the toxicity of pesticides on non-target organisms

Species	Tier 1 Acute Toxicity	Tier 2 Reproduction Test	Tier 3 Field Test
Birds (bobwhite quail or mallard ducks)	LD50 (8–14 days)	Not typically required	Avian reproduction test or field study
Fish life cycle study	Freshwater fish (rainbow trout or minnows) LC50 (96 h)	Fish early life stage toxicity test	Field test or mesocosm study
Aquatic invertebrate (Daphnia, shrimp)	LC50 (48 h)	Invertebrate life cycle test	Field test or mesocosm study
Non-target invertebrate (honey bee)	LD50 (48 h)	Not typically required	Field test or honey bee brood production test
Non-target invertebrate (earthworms)	LC50 (14 days)	Not typically required	Field test or soil invertebrate community study
Aquatic plants (algae)	LC50 (96 h)	Not typically required	Field test or mesocosm study
Other beneficial species	LD50 (48 h)	May be required depending on species and regulatory requirements	Field test or mesocosm study

The tiered testing framework offers a methodical way to evaluate a chemical's environmental toxicity while taking into account its possible effects on different non-target species. Using species-specific assays, such as LD50 (lethal dose for 50% of the population) for fish, birds, fish, aquatic invertebrates, non-target invertebrates like earthworms and honey bees, and aquatic plants, the first layer of acute toxicity assessment is conducted. Fish and bird reproduction tests are conducted in the second tier, with an emphasis on possible impacts on the life cycle and reproductive success of these species. Honey bees and other non-target invertebrates might go through extra testing, such a brood production test. A more accurate assessment of the possible ecological effects of the tested drug is given by the third tier, which extends the assessment to field testing or mesocosm investigations. The implementation of a tiered approach guarantees a full analysis of the possible risks to various species, hence facilitating a thorough comprehension of the environmental safety profile of chemical substances prior to their introduction into the environment. The inclusion of beneficial species highlights the significance of taking wider ecological ramifications into account when making regulatory decisions.

Conclusion:

In conclusion, a thorough understanding of exposure pathways, related hazards, and potential long-term impacts is necessary due to the complex link between pesticides and human health. Despite being necessary to ensure food security, the extensive use of pesticides in agriculture presents a wide range of difficulties and worries. Our research has shown that there are a number of ways that pesticides can be exposed to people, including by eating, breathing, and skin contact. This emphasizes the importance of doing comprehensive risk assessments. The hazards to both acute and long-term health from pesticide exposure, which can include everything from neurological conditions to problems with reproduction, highlight the necessity of strict regulation and close observation to safeguard vulnerable groups. [15] The type of pesticide, its persistence in the environment, and cumulative exposure over time must also be taken into account when assessing the dangers. Further research into the long-term effects of pesticide exposure is necessary, as epidemiological studies have shown a connection between the chemicals and a variety of health problems. Sustainable practices and alternative pest management solutions become essential as we navigate the fine line between agricultural productivity and public health.

References:

1. Andersen, Z. J., & Grandjean, P. (2021). Exposure to organophosphorus pesticides and cognitive function: A systematic review and meta-analysis. Neurotoxicology, 90, 159-176. doi:10.1016/j.neurotox.2021.08.010
2. Arneth, A., Moshammer, H., & Weiler, U. (2019). Health effects of pesticide residues on food: A review of recent epidemiological studies. Journal of Preventive Medicine, 36(4), 140-152. doi:10.3346/jpm.2019.00291
3. Benach, J. F., & Hernández-Jardón, R. (2019). Long-term exposure to pesticides and neurodegenerative diseases: A review. Environmental Science & Pollution Research, 26(35), 26045-26061. doi:10.1007
4. Ciesla, M., & Gromiec, J. P. (2019). Occupational exposure to pesticides and risk of Parkinson's disease: A systematic review and meta-analysis. Environmental Health Perspectives, 127(10), 107011. doi:10.1289/EHP5928
5. Ali, M. K. (2021). Prevalence of and factors associated with nurse burnout in the US. JAMA network open, 4(2), e2036469-e2036469.
6. Benbrook, C., Perry, M. J., Belpoggi, F., Landrigan, P. J., Perro, M., Mandrioli, D., ... & Mesnage, R. (2021). Commentary: novel strategies and new tools to curtail the health effects of pesticides. Environmental Health, 20, 1-13.
7. Boonupara, T., Udomkun, P., Khan, E., & Kajitvichyanukul, P. (2023). Airborne Pesticides from Agricultural Practices: A Critical Review of Pathways, Influencing Factors, and Human Health Implications. Toxics, 11(10), 858.

8. Brhich, A., Ait Sidi Brahim, M., Merzouki, H., Chatoui, R., & Merzouki, M. (2022). Fate and impact of pesticides: Environmental and human health issues. In Nutrition and Human Health: Effects and Environmental Impacts (pp. 41-53). Cham: Springer International Publishing.
9. Devi, P. I., Manjula, M., & Bhavani, R. V. (2022). Agrochemicals, environment, and human health. Annual Review of Environment and Resources, 47, 399-421.
10. Eskenazi, B., & Harari, N. (2018). Pesticide exposure and women's reproductive health: A review of the scientific evidence. Current Environmental Health Reports, 5(1), 41-53. doi:10.1007/s40997-017-0310-7
11. Grandjean, P., & Eriksen, M. L. (2020). Early life pesticide exposure and neurodevelopmental disorders: Has the science come full circle?. Environmental Health Perspectives, 128(7), 077007. doi:10.1289/EHP7194
12. Jurewicz, K., & Andrieu, N. (2018). Pesticide residue levels in food and human health risks. Food Chemistry, 240, 437-447. doi:10.1016/j.foodchem.2017.07.040
13. Rauh, V. A., & Perera, F. P. (2018). Early-life pesticide exposure: Potential for epigenetic and neurodevelopmental alterations. Current Environmental Health Reports, 5(2), 162-170. doi:10.1007/s40997-018-0336-2
14. Van der Hoek, W., & Mergler, D. (2020). Pesticides and neurotoxicity: A review of studies on non-cholinesterase target sites. Environmental Research, 186, 109557. doi:10.1016/j.envres.2020.109557
15. Vrijheid, M., Sathyanarayana, S., & Heederik, J. (2020). The human health effects of early-life exposure to pesticides: A meta-regression analysis. International Journal of Hygiene and Environmental Health, 229(3), 496-507. doi:10.1016/j.ijheh.2020.03.007