NJESR/November-2024/Volume-6/Issue-11 E-ISSN-2582-5836
DOI-10.53571/NJESR.2024.6.11.52-63

Heavy Metals In Agricultural Cultivated Products Irrigated With Wastewater In Sriganganagar

Mrs.Sunita Nagpal
Associate Professor
Department Of Chemistry
Dr.Bhim Rao Ambedkar Government College
Sriganganagar

(Received-10October2024/Revised-25October2024/Accepted-10November22024/Published-29November2024)

Abstract

Indiscriminate industrialization and urbanization have harmed the environment. In many semi-urban parts of India, a common environmental problem is the release of poorly treated wastewater from homes, industries, and cities into the environment. This has caused the dirt and water to get worse. Because of less clean water, Indian farmers have started using wastewater as a cheaper and easier source for watering crops. But this has also caused more harmful chemicals to get into the soil. Some of these chemicals, called persistent pollutants, include metals like cadmium, copper, chromium, lead, mercury, and a few others. These metals are dangerous because they don't break down easily, stay in the body for a long time, and can interact with living things. In Sri Ganganagar, where crops are watered with wastewater, studies have found that vegetables may contain heavy metals like iron, manganese, chromium, and zinc because these metals are common in the local soil and water. Other metals like lead, nickel, copper, cobalt, and cadmium are also present, though in smaller amounts. These harmful substances can get into the food we eat, which could harm our health. Since using wastewater for irrigation can’t be stopped in Indian (semi)-urban areas because there’s a growing need for water, it’s important to understand how this affects people. This article brings together research from India about heavy metals in vegetables. It also tries to figure out the health risks from eating vegetables grown in areas where wastewater is used for irrigation.

Keywords: Accumulation, Contaminants, Heavy Metals, Irrigation, Nonbiodegradable, Sewage

Introduction

Water conservation is being studied by scientists around the world. As the population grows, the need for fresh water for farming and daily use is rising, which can threaten sustainable development in some regions. In many semi-urban areas of India, the availability of clean surface water or groundwater has decreased [1]. Because of this, farmers are turning to cheaper and more accessible sources of water for irrigation, such as treated and untreated wastewater from cities and industries. Using wastewater for farming and raising fish has been common in many parts of the world, including India, for a long time. Even though there are no full numbers on how much farmland uses wastewater, a study by the International Water Management Institute (IWMI) found that about 73,000 hectares of farmland near cities in India use wastewater for irrigation. [1]

In many countries, both developed and developing, wastewater from cities is usually released into the soil. In developed countries where environmental rules are strict, a lot of wastewater is treated well before it is used for farming. But in many developing countries, these rules are not always followed, which can harm the environment and the ecosystem.

In India, farmers are using wastewater because it has useful nutrients like nitrogen, phosphorus, and potassium (NPK) that help crops grow[2].However, using this kind of water for irrigation can cause harmful substances to enter the crops and plants. Among these harmful substances, heavy metals are the biggest danger. Heavy metals are poisonous, stay in the environment for a long time, and build up in the body over time. Using wastewater that has heavy metals in it for irrigation can cause these metals to accumulate in the soil beyond safe levels. This can make the crops grown in such soil harmful to human health.

Fruits and vegetables are important for good health because they give the body nutrients like carbohydrates, proteins, vitamins, minerals, and fiber. [1-2]

They also help balance acid in the digestive system. Some metals, like aluminum, arsenic, cadmium, lead, and mercury, are not needed by the body and can be harmful. These heavy metals, especially lead, arsenic, mercury, cadmium, and chromium, can cause serious health problems such as kidney failure, cancer, and issues with the nerves and liver[3].Vegetables grown in soil that has heavy metals can have more of these metals in them than vegetables grown in clean soil. [1]

How much of these metals gets into different parts of a vegetable depends on the metal's chemical form and how the plant works. Also, the harmful effects of these metals depend on how much is present and the form it takes. The structure and function of the plant also influence how much metal it absorbs. For example, leaves and roots take in more metals than stems and fruits. Since wastewater irrigation cannot be stopped in Indian peri-(semi)-urban areas because the need for irrigation water keeps growing, this study also looks, at least in a general and partly measured way, at how safe it would be to use wastewater for farming in Indian places. This article brings together the findings from studies that have looked at wastewater irrigation across India. It also tries to understand how using wastewater affects the movement of heavy metals into the soil and then into the plants grown in each study area. Finally, it aims to check the risk that these heavy metals pose to people through the food chain, as they move from the plants to the soil and then to humans. Heavy metal pollution in plants and water is a big problem around the world and needs attention[4]. Heavy metals in higher amounts than usual are very harmful to both plants and animals. The sources of heavy metal pollution in different ecosystems include the heavy use of fertilizers, pesticides, irrigation, air pollution, and industrial waste. Knowing the exact levels of heavy metals, the forms they take, and how they depend on the physical and chemical properties of the soil helps in managing the soil properly. Poor management of soil and water can increase the movement of heavy metals, leading them to enter the food chain. Most heavy metals stay on the surface of the soil and in the top layers of sediments in water basins. They mix with other materials in these layers and change their properties[4-5]. The pH of the soil, the amount of mobile heavy metal, and the presence of organic matter in the sediments act like a buffer, keeping these metals stored for a long time. In the past, a study was done in Bikaner to assess heavy metal contamination in vegetables grown using wastewater for irrigation. The results showed higher levels of iron, manganese, zinc, and copper. There wasn’t much information about heavy metal exposure in that region. Therefore, this study was carried out to find out heavy metal issues and their contamination in water, soil, and selected crops in Sri Ganganagar district. Study area: Ganganagar district is located in the northernmost part of Rajasthan. It covers an area of around 11,154.66 square kilometers and is surrounded by Bikaner and Hanumangarh districts[6]. The district has an arid climate, with hot summers and cold winters. The southwest monsoon season occurs from June to mid-September, followed by the post-monsoon period until the end of November. Major crops grown in large areas include wheat, mustard, and cotton, along with other crops like guar, bajra, sugar cane, and grams. The northern part of the district has sierozems or arid soils that are light yellowish-brown to pale in color. A layer of kankar (calcareous concretions) is found at a depth between 75 to 100 cm. The soils are deep and moderately drained, with moderate to slow permeability. The water-holding capacity and natural fertility of the soils are generally low. Loamy sand and sandy loam are the main soil types in this area. Four major crops—Cyamopsis tetragonoloba, Vigna radiata, Pennisetum glaucum, and Gossypium arboretum—were selected for the study on heavy metal contamination. These crops were chosen based on the areas where they are grown[7].

Materials And Methods

Design Of The Study

The study was designed based on a review of existing research (within India) focusing on wastewater irrigation and the accumulation of heavy metals in crops and soils where these crops are grown. [7]

The search was conducted in international databases such as Scopus and ScienceDirect, and also on Google Scholar a few times. Keywords like sewage farming, sewage farming in India, heavy metals, health effects, and transfer factor (TF) were used to narrow down the search. In the end, 40 relevant research papers (out of 65) were selected for data analysis. This study included both urban and rural areas across India where wastewater has been used for irrigation for a long time. For analyzing heavy metals in water, soil, and crops, samples were collected from agricultural areas in Sri Ganganagar during the post monsoon season. Water samples were collected in clean plastic bottles that were thoroughly washed with nitric acid and rinsed several times with distilled water. Soil samples were taken from the top mineral layer (5-20 cm), and leaf samples from crops were collected after the rainy season from areas with extensive agriculture. Before analysis, soil samples were air-dried at 20°C and ground in a mortar until they passed through a 2 mm sieve. The leaves of selected crops were washed thoroughly with deionized water to remove particles, then dried at 70°C and ground into a fine powder. A 0.5 gram sample of each crop and soil was weighed and placed in a hard Borosil glass tube. A mixture of concentrated nitric acid and perchloric acid in a 4:1 ratio was added to each sample. The samples were kept in a water bath for 5 to 6 hours or until they were completely digested and clear. Then, 3 to 4 drops of 30% hydrogen peroxide were added to neutralize and dissolve the fat. After cooling, each sample was diluted to 10 ml with deionized water and transferred to a sterilized Borosil glass vial, where it was stored at room temperature before analysis. [8]

Collection Of Data

A systematic search was done to find research papers on wastewater irrigation and the accumulation of heavy metals in vegetables.The search also included studies on heavy metals in soil and the sources of irrigation water. Research papers were selected if they discussed the use of wastewater for irrigation, both experimental and review-based studies, and papers on the concentration of heavy metals in vegetables. Studies on transfer factors and health risk assessment were also included. From the selected papers, a detailed analysis was done on the concentration of heavy metals in agricultural products. For this review, data such as the source of irrigation water (wastewater), types of vegetables, the nature of the vegetable (leafy versus non-leafy), location of the study, and the concentration of heavy metals were analyzed. [8]

Protocols And Analysis For Soil, Plant, And Water Samples

All laboratory tests for soil and water samples were done using the methods described in Handbook 60 by the U.S. Laboratory Staff (1969), or as mentioned otherwise. To determine the soil texture, the hydrometer method was used. The International Textural Triangle, which helps classify soil based on the amounts of sand, silt, and clay, was used to identify the soil texture class. [9]

Analysis Of data

The data were studied based on the levels of heavy metals found in different parts of plants and also based on the transfer factor (TF) of heavy metals. The TF is the ratio of heavy metal concentration in plants compared to that in soil. A risk-assessment analysis was done to show the health risks linked to different types of heavy metals and the consumption of various agricultural products. This was done using the hazard quotient (HQ) index. Other measures, like the enrichment factor of soils and the air accumulation factor of heavy elements in vegetables, were discussed whenever data were available. [10]

Discussion

Sources Of Heavy Metals

Both natural and human-made sources contribute to the presence of heavy metals in wastewater and irrigated soils. Natural sources include soil erosion, volcanic eruptions, urban runoff, and aerosol deposition. On the other hand, human activities such as industrial processes and household practices are major anthropogenic contributors. [10]

With the growing population and associated human activities, the concentration of heavy metals in wastewater has increased.Urban areas are particularly significant in the distribution of metals in sewage and soil. Domestic wastewater, which makes up a large part of urban wastewater, includes sources like food, detergents, cosmetics, sanitary fittings, kitchen waste, laundry water, bath water, and toilet discharge. The possible sources of various heavy metals in domestic wastewater are listed in Table 1. [10]

Table 1: Sources of heavy metals in domestic wastewater

Metal	Sources
Pb	Sewer hookups and pipelines, wastewater from laundry
Cr	Cleaning of metal cookware
Ni	Stainless steel materials, cleaning of cookware, feces,
Zn	Food, plumbing materials, detergents, toothpaste, shampoo, and deodorants
Fe	Food coloring, diet supplements, steel and iron products, water supply pipes, paints, and cosmetics
As	Medicines, washing products, glass, wood preservatives, garden products
Mn	Pesticides, food products like grains, nuts, tea leaves
Cu	Copper piping corrosion
Cd	Washing powder, dish wash detergents

Industrialization has caused heavy metal contamination in the soil. Toxic chemicals build up in the soil because of fast industrial growth, unplanned city expansion, and long-term use of large amounts of fertilizers and pesticides. The main sources of pollution from human activities are linear sources (from vehicle transport), surface sources (from household emissions), and point sources (like fuel burning and industrial smoke from chimneys). Different industries create various heavy metals, such as chromium from paint and metal industries, nickel from steel production, and cadmium from smelting. Road traffic also produces certain heavy metals like lead. For many years, lead was added to gasoline, and when it burned, it released lead into the environment, but this source is becoming less common over time. Studies have found that street dust along busy roads is a major pollutant in urban soils. Roads with heavy traffic can also pollute the soil because vehicles release exhaust that contains metal-rich particles. [8-10]

Heavy metal pollution in soil is a big concern near industrial areas, as it harms the environment. Some studies show that using wastewater for irrigation changes the physical and chemical properties of soil. Research from India indicates that using wastewater to water crops increases the amount of heavy metals in the soil and in the food grown. [8]

The amount of metals in the soil affects how much of them ends up in vegetables. Natural rock formations are a source of these metals in the soil. Metals also get into farmland through organic and mineral fertilizers, especially those containing calcium and phosphates. Pesticides and fungicides are also sources of metals in the soil. [7]

The condition of the soil plays a big role in how available heavy metals are for plants to take in. Factors include the soil's pH level, type of soil, moisture content, and the initial metal concentration in the soil. For example, soils with certain grain sizes tend to hold more cadmium. Studies also found that the cadmium content in crops like wheat is, to some extent, connected to the characteristics of the top layer of soil, including the total and soluble levels of cadmium in the soil. [8]

Heavy Metals In Vegetables

Figure 1 indicates the different study locations of India whose findings have been covered in this article. the mean concentration of various heavy metals, for example, Zn; Cu; Mn ; Cr; Cd; Pb , and Ni from those locations. Likewise, the concentration of heavy metals in leafy and nonleafy vegetables from several parts of India has been reported in the literature, and these are reported in Tables 2 and 3. [8]

Table 2: Concentration of heavy metals in the edible portion of leafy vegetables[8]

Study area	Heavy metals	Sources of heavy metals	Types of sample vegetables	Key findings
Outskirts of Bombay city	Pb, Cd, Cu, and Zn	Atmospheric deposition	Amaranthus	The highest concentration of Cd
Kanpur	Fe, Cr, Zn, Mn and Cu	Treated tannery wastewater is a source of pollution	Amaranth, spinach, coriander,	A higher accumulation of Cr in edible parts of leafy vegetables was observed

Amritsar, Punjab	Cd, Cu, Fe, Pb, and Co	Effluents from industrial units	Coriander, fenugreek, mint, spinach	Spinach was the most hazardous for cobalt, and copper was highest in spinach
Rewa, Madhya Pradesh	Fe, Zn, Cu, Pb, Cd, Mn, and Cr	Effluents from a cement factory	Spinach	Pb, Cd, and Cr were higher in spinach when compared to nonleafy plants
Sri Ganganagar district, Rajasthan	Fe, Mn, Cu, and Zn	Continuous and long-term irrigation with wastewater	Spinach, mustard, peppermint, coriander	Spinach has shown a higher accumulation of Fe, Mn, Cu, and Zn,
Hyderabad	Zn, Cr, Cu, Ni, Co, and Pb	Sewage disposal to the river and use of river water as a source of irrigation	Forage grass, coconut, spinach, amaranthus, coriander leaves, mint leaves	High amounts of Zn followed by Cr and Ni in spinach and amaranthus
Delhi	P, K, S, Zn, Cu, Fe, Mn and Ni	Sewage effluents are the primary source of pollution	Gobhi, Sarson, spinach, cauliflower	Spinach, gobhi, and sarson have a comparatively higher accumulation of heavy metals than nonleafy ones
Suburban of Varanasi	Cu, Zn, Cd, Pb, Ni, and Cr	Industrial effluents	Spinach, amaranthus, cabbage	Cu and Cr were higher in leafy vegetables
Lucknow	Cr, Ni, Zn, Cu, and Cd	Effluent from an electroplating industry	Spinach	Leafy vegetables have a greater accumulation
Bangalore	Fe, Zn, Cu, Ni, Cr, Pb, and Cd	Sewage is the main source of pollution	Spinach	Heavy metal contamination in vegetables is much in leafy vegetables when compared to nonleafy vegetables
Varanasi	Cd, Ni, Cu, Cr, Pb, and Zn	Sewage sludge	Spinach	Increase heavy metal concentration of Cd, Ni, and Zn
Northern India	Cd, Cr, Ni, and Pb	Treated sewage	Spinach, cabbage	Higher concentration of heavy metals in leaf when compared to other storage organs
Titagarh, West	Pb, Zn, Cd, Cr, Cu, and	Municipal wastewater irrigation	Lettuce, pudina, cauliflower, spinach,	Pb, Zn, Cd, Cr, and Ni concentrations in all the leafy

Bengal	Ni		coriander	vegetables were beyond the safe limits
Korba, Chhattisgarh	Fe, As, Cr, Mn, Cu, Zn, Pb, Cd, and Hg	Industrial deposition	Amaranthus., spinach, coriander	High health risk index for As in all the tested vegetable
Vadodara, Gujarat	As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn	Use of industrial effluent for irrigation	Spinach, coriander, cabbage, dill	Spinach and cabbage showed high accumulation and translocation of As, Cd, Cr, Pb, and Ni in their edible parts

Table 3: Concentration of heavy metals in the edible portion of nonleafy vegetables[8]

Study area	Heavy metals	Sources of heavy metals	Types of sample vegetables	Key findings
Visakhapatnam, Andhra Pradesh	Pb, Zn, Ni, and Cu	Deposition of metals due to emissions from industrial and transport sectors	Tomato, lady's finger, capsicum	Higher levels of Pb concentrations in vegetables grown in an industrial area
Amba Nalla in Amravati City, Maharashtra	Pb and Cd	Wastewater from domestic sources	Tomato	Concentration more than the permissible limit
Vadodara, Gujarat	As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn	Use of industrial effluent for irrigation	Radish, tomato, chili, brinjal and okra	Radish, tomato, and chili showed higher accumulation of As, Cd, Cr, Pb, and Ni in their edible parts
Amritsar, Punjab	Fe, Co, Cu, Cd, and Pb	Wastewater drain	Radish, turnip	HQ higher than the safe limits in spinach
Delhi	P, K, S, Zn, Cu, Fe, Mn, and Ni	Sewage effluents are the primary source of pollution	Rice, wheat, sorghum, maize, oats, cucumber, radish	Ni has the greatest potential, followed by Zn, Fe, Mn, and Cu in the plants
Kanpur	Fe, Cr, Zn, Mn, and Cu	Treated tannery wastewater is		

Heavy metal concentrations in soil and crops vary based on the source of contamination and the type of agricultural produce[8]. In Delhi's peri-urban regions, where crops like spinach and lady's finger are cultivated and exposed to industrial effluents, sewage sludge, and vehicle emissions, heavy metals were found in varying levels. Spinach showed higher concentrations of Cu (7–50 mg kg^{-1}), Zn (51–282 mg kg^{-1}), Cd (1.4–9.0 mg kg^{-1}), and Pb (1.7–9.2 mg kg^{-1}) compared to lady's finger. The difference in metal concentrations in spinach and lady's finger was attributed to their differing abilities to intercept metal ions, the transport mechanisms (mass flow and diffusion), translocation from roots to shoots, and their accumulation and retention capacities. In the case of vegetables grown in late autumn in suburban Varanasi, leafy vegetables like spinach had higher Cu and Cr levels than non-leafy vegetables like brinjal and lady's finger[8].

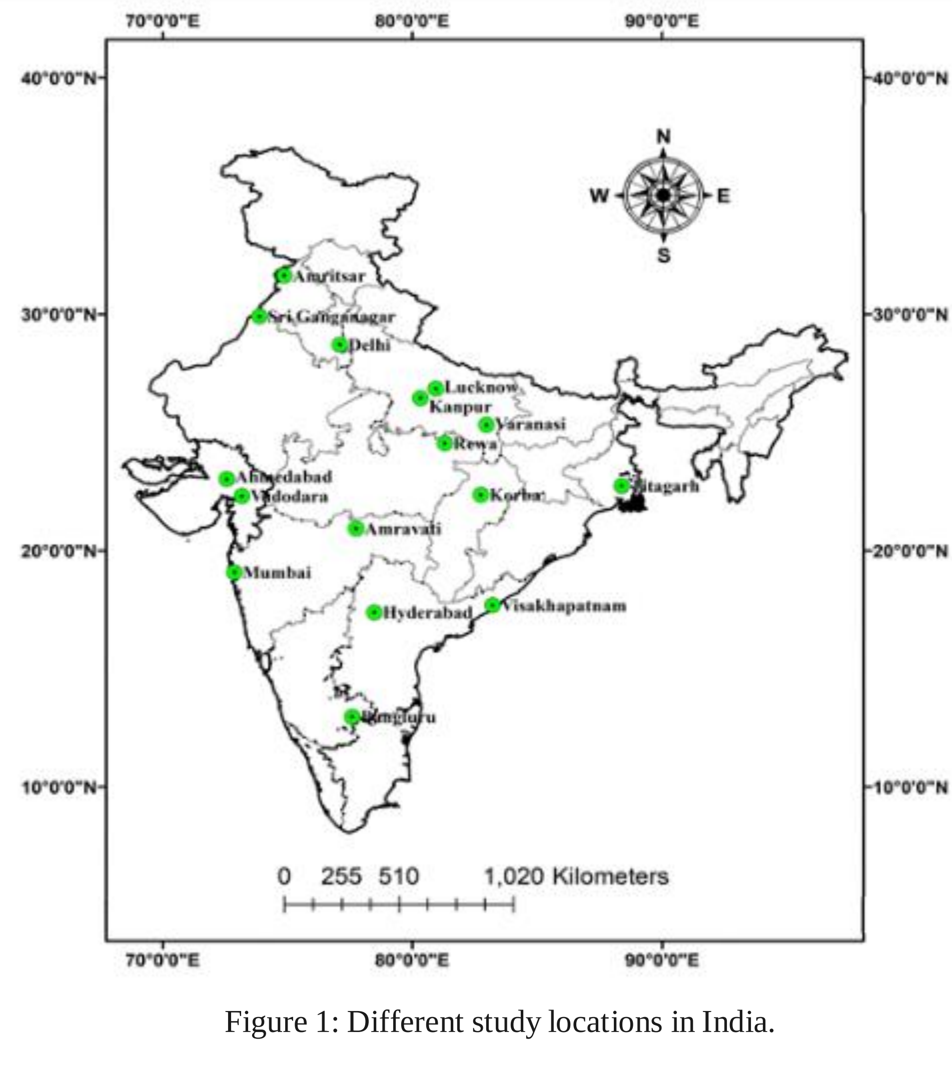

Figure 1: Different study locations in India.

In the Dinapur area of Varanasi, Cu, Pb, and Ni levels were higher during winter than summer, likely due to the rapid decomposition of organic matter in summer, which releases heavy metals into the soil solution. An assessment of the health risks posed by heavy metals (Fe, As, Cr, Mn, Cu, Zn, Pb, Cd, and Hg) in vegetables grown in the coal-burning basin of Korba, India, revealed that soils were enriched with As, Cd, and Pb, with Al-normalized enrichment factors of 27 (As), 19 (Cd), and 11 (Pb), primarily linked to coal-burning activities. Spinach showed the highest metal pollution (16.2 mg kg^{-1}) compared to brinjal (3.1 mg kg^{-1}), likely due to the higher biomass of leafy vegetables. This led to a higher health risk index for spinach, especially for As. [6-8]

Conclusions

By reviewing published studies, we assessed the impact of wastewater irrigation in (semi)-urban areas of India. Given the likelihood that wastewater irrigation will continue due to increasing water demand, it is essential to evaluate how wastewater affects the transfer of heavy metals to soils and subsequently to crops grown in them. This study aimed to determine the concentrations of various heavy metals in soil, water, and common crops in Sri Ganganagar district. It was found that water samples showed heavy metal concentrations in the order Fe > Mn > Cr > Zn > Pb > Ni > Cu > Co > Cd, while soil samples showed a similar trend. Co and Cd were the least concentrated in both water and soil. The source of heavy metal contamination in the ecosystem is likely due to the release of untreated industrial and domestic wastewater, excessive use of pesticides and synthetic fertilizers, and atmospheric deposition from vehicular emissions. These heavy metals can cause significant health issues for humans. Therefore, regular monitoring of heavy metals is crucial for addressing related health risks.

References

[1]. Mohanty, B., & Das, A. (2023). Heavy metals in agricultural cultivated products irrigated with wastewater in India: a review. AQUA—Water Infrastructure, Ecosystems and Society, 72(6), 851-867.

[2]. Singh, I., & Gautam, A. K. (2023). Sewage Irrigation Cause Heavy Metal Accumulation In Fenugreek-Methi (Trigonella Foenum-Graecum) Field Crop: A Case Study. International Journal of Pharmacology & Biological Sciences, 17(2).

[3]. Singh, I., & Gautam, A. K. Sewage Irrigation Cause Heavy Metal Accumulation in Spinach (Spinacia oleracea) Field Crop: A Case Study.

[4]. Saini, P., & Gautam, A. K. Effect of Sugar Mill Effluent Irrigation Practices on Chemical Properties and Metal Built-Up in Soil: A Case Study of Sri Karanpur.

[5]. Jangde, V., Choubey, S., & Markam, D. K. (2022). Sustainable Circular Economy: Transforming Fly Ash into Valuable Compost. J. Environ. Nanotechnol, 13(2), 470-476.

[6]. Gour, M., Mehrada, N., Rathore, S., Jain, R., & Sharma, M. M. (2023). Nutrient reclamation in a few districts of Rajasthan through organic farming. Recent Advances In Material Science And Computational Techniques (Ramsact), 2723(1), 020026.

[7]. Mathur, M., & Mathur, P. (2023). Restoration of saline and sodic soil through using halophytes as agroforestry components. In Sustainable Management and Conservation of Environmental Resources in India (pp. 311-354). Apple Academic Press.

[8]. Niranjan, B. H., Govindaiah, P. M., Yandigeri, M. S., Gourkhede, D. P., Fairoze, N., V, E. A., & Rao, S. N. (2021). Bioconversion and Performance of Black Soldier Fly (Hermetia illucens) in Converting Organic Poultry Waste Materials into High Value Products and Fertilizers. Waste and Biomass Valorization, 15(9), 5559-5572.

[9]. Niranjan, B. H., Govindaiah, P. M., Yandigeri, M. S., Gourkhede, D. P., Fairoze, N., & Rao, S. B. (2021). Bioconversion and Performance of Black Soldier Fly (Hermetia illucens) in Converting Organic Poultry Waste Materials into High Value Products and Fertilizers. Waste and Biomass Valorization, (9), 5559-5572.

[10]. Mandal, S., & Mandal, S. (2022). Green Biomaterials from plants: Harnessing Nature for Sustainable Solutions. Current Pharmaceutical Letters And Reviews, 11-24.