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Heavy Metal Uptake in Cauliflower: Health Risks

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ABSTRACT:

Due to the serious risk of consuming food contaminated with heavy metals, food safety and quality protection are essential and should receive significant attention. The current investigation was done in this context to assess the potential health concerns associated with heavy metal uptake by cauliflower curds. Six farms, evenly dispersed between contaminated and unpolluted areas in South Greater Cairo, Egypt, were used to sample the soil and cauliflower plants in order to examine their chemical properties and growth factors. Except for Ni, the predicted heavy metals all had pollutant load indices (PLI) that were higher than 1.

KEYWORDS:

Concentrations, Cauliflower, Heavy Metal, Soil Samples.

I. INTRODUCTION

Researchers pay close attention to this issue and the health risks associated with consuming contaminated foods since food security and safety is a global public concern. It was predicted that by 2050, the world's population expansion would cause the food consumption to double. In order to support food security, agricultural productivity will therefore advance quickly. Since there is a significant risk associated with consuming food contaminated with heavy metals, food quality protection and safety should receive significant attention. Crop plants may transport and concentrate heavy metals in high concentrations in their edible portions even at low soil heavy metals content. This is true even at low soil heavy metals content. In addition to the anthropogenic discharge of industrial and sewage effluents, atmospheric deposition, and fossil fuel, the global industrial revolution is a significant source of elevated heavy metals concentration. Wastewater is a popular alternative irrigation source in developing nations for irrigation of high-value food crops and to boost agricultural yields in urban settings.

Food plants are a significant source of nutrients such vitamins, minerals, and carbohydrates that are essential for human health. The population consumes a variety of vegetables grown on sewage and industrial waste, which poses major health risks due to the buildup of heavy metals in the body from eating these contaminated food plants. The Brassicaceae family includes the significant vegetable cauliflower which is farmed all over the world and has a variety of applications, including as a vegetable or an ingredient in soups, salads, and other dishes. Approximately 16.40 million tons of cauliflower are produced globally on an area of 8.88 million ha. It contains significant phytochemicals that guard against diabetes, cancer, and cardiovascular illnesses and is a great source of dietary fiber, vitamins, and minerals. Furthermore, wastewater is commonly used to irrigate the cultivation and consumption of the vegetable crop cauliflower in various developing nations, like Egypt. Heavy metal pollution of agricultural lands is a significant environmental problem since it can harm crop development, yield, quality, and safety of agricultural goods, which endangers human health. In order to determine the risk level and maintain the ecosystem, it is important to analyses the levels of heavy metals in plants.

Additionally, it is essential to determine the presence of heavy metals in plants to reduce their concentration in crop plants and prevent their toxicity. Additionally, the health risk assessment may identify polluted from unpolluted areas, identify the areas with the highest risk of contamination, and manage pollutants that endanger human health all conducted studies to estimate the content of heavy metals in cauliflower crops and the potential health concerns associated with their consumption.

In order to prevent significant health issues brought on by heavy metals entering the food chain and their invisible toxicity, there is a systematic assessment of the necessity for making important decisions. As a result, the current study was carried out to ascertain the effects of wastewater-irrigated soils on the development and production of cauliflower plants as well as to assess the potential for heavy metal concentration in the edible parts and the associated health hazards [1], [2].

Resources and Procedures

Polluted location that absorbs wastes from anthropogenic activity, agricultural drainage, and industrial effluents. It was situated in the Ekhsas district of south Cairo Province, Egypt (29° 47' 29.31"N - 31° 18' 38.05"E), which is home to around 7.79 million of Greater Cairo's 18.29 million consumers (Elawa, 2015). The soils in this location may experience rising water levels as a result of the poor drainage systems, which could lead to desertification. The unpolluted (reference) site, in contrast, receives irrigation water from the Nile River, which does not receive any waste discharge from industry or local government. It was situated in the southern Giza Province village of Mazarin (29° 52' 16.94"N - 31° 16' 14.74"E).

The study locations' agricultural fields, which run along the Nile Valley, were distinguished by alluvial soils. The research area, which included the two locations, had an average annual rainfall of 1.67 to 2.13 mm, a mean annual temperature of 21.08 oC, and an average yearly relative humidity of 52.68 to 56.08%. In comparison to the unpolluted site, the contaminated site's irrigation water is more saline, has a higher pH, and contains more heavy metals.

Chemical Elements

From each of the polluted and unpolluted farms, three composite oven-dried samples of the cauliflower roots and curds (n = 36) were gathered and ground into a powder for further examination. The molybdenum blue method was used to determine P using a spectrophotometer (CECIL CE 1021), and the flame photometer (CORNING M410) to determine K. The total nitrogen (N) was assessed using the Kjeldahl method. According to Lowry et al. (1951), the total soluble proteins were calculated, and the total soluble sugars were calculated using the enthrone method. The acid digestion method was used to measure the heavy metal concentration of the various plant parts. While a 1 g powdered sample was digested in 20 ml of a 5:1:1 tri-acid solution of HNO3, H2SO4, and HClO4 until a translucent color was seen (Allen, 1989). The digested material was then filtered and diluted to 25 ml with double-distilled water. Using a Pie Unicast 1900 Recording Flame Atomic Absorption Spectrophotometer, the concentrations of Pb, Cd, Co, Fe, Cu, Ni, MN, Zn, Cr, and V were measured. The detection thresholds for the heavy metals were as follows (in g l1): 15.0 for Pb, 0.8 for Cd, 9.0 for Co, 5.0 for Fe, 1.5 for Cu, MN, and Zn, 6.0 for Ni, 3.0 for Cr, and 2.0 for V. The overall detection limits had a 98% confidence level. All of the approaches listed above were taken from Allen [3], [4].

II. DISCUSSION

The buildup of heavy metals from soil or water into food systems is a major concern that needs to be addressed on a global scale. The cauliflower plants currently growing in polluted soil and irrigation water have been noticed to exhibit pigment paleness. The amount of chlorophyll a and b was significantly reduced in plants grown in polluted farms, and this may be explained by the high capacity of this plant to accumulate heavy metals, which destroy chloroplasts and inhibit chlorophyll synthesis or reduce the number of chloroplasts in the leaves. Chlorophyll production is inhibited by toxic heavy metals because they accelerate chlorophyll breakdown. As a result of the high salinity of the polluted fields, Farooq et al. and Gala et al. reported a decrease in the chlorophyll content of cauliflower, which may be brought on by an increase in chlorophylls activity at higher salinity levels. In addition, heavy metals may also activate the pigment enzyme and quicken the degradation of the pigment.

The biomass and yield of cauliflower were remarkably affected by the sources and concentrations of nutrients. In fields with less pollution than in those with more pollution, the cauliflower tissues acquired higher levels of inorganic and organic nutrients. These nutritional values exceeded those noted for Spanish, Australian, and American cauliflowers cauliflower plants collect more macronutrients (N, P, and K), which promote the development of curd. Additionally, studies by Penman et al. and Kumar et al. supported the idea that while a larger concentration of macro- and micronutrients may boost crop output, it may also have toxic and detrimental effects on biological behavior. In addition, Collazo-González et al. found that the protein content of healthy cauliflower curd was 15.6%, whereas the current study found that it was 8.23 and 10.79% in polluted and unpolluted plants, respectively.

Long-term irrigation with dirty water can alter the soil's physicochemical composition and encourage the uptake of heavy metals by vegetable crop plants. In the current study, the heavy metal analysis of cauliflower plants revealed considerable variations in the plant tissues between contaminated and unpolluted areas. The findings of Ur Rahman et al., who found that food crops irrigated with wastewater had greater heavy metal contents than crops irrigated with freshwater, were in agreement with the findings of this study. In accordance with Kumar et al. on the same plant, the roots of the cauliflower plants accumulated the majority of heavy metals, with the exception of Cr and Co. Furthermore, they accumulated more metals from polluted farms than from clean ones. In comparison to soil amended with sludge and soil irrigated with wastewater the amount of heavy metals deposited in the curd at the polluted location was greater. Vegetable crops watered with sewage and industrial effluent have been found in earlier studies to gradually accumulate large levels of heavy metals.

Comparing the current results to previously published average levels in various vegetables, it was found that the concentration of Cd, Pb, and Zn was extremely high. The cause for the high concentration of heavy metals in cauliflower tissues could be the ongoing addition of metals by irrigation with tainted water and low metal leaching into the lower layers of soil The variation in the absorption and accumulation potential of components in the cauliflower curds was confirmed by Jahangir et al. and Kalisz et al. Heavy metals from the soil may be taken up by cauliflower plants, where they may concentrate in the roots and maybe go to the edible curds. Due to the reduced movement of these metals from below- to above-ground portions, cauliflower plants' bioaccumulation capability revealed that they mostly retain heavy metals in their roots. In the polluted farms, the examined heavy metals had BFs that were in the following order: Cd > Ni > V > Fe > Co > Pb > Cr > MN > Cu > Zn. Schemata and Gala predicted similar outcomes for cucumbers, whereas Gala et al. Predicted them for cabbage and common mallow, respectively.

On the other hand, some heavy metals like Cr, Co, Cu, Fe, Pb, and V could translocate from the belowground roots to the aboveground curds, suggesting that cauliflower may operate as a phytoextractor and metal accumulator. These findings were in agreement with those of Gala et al. and Enid et al. for spinach. The public consumers will be subjected to significant health hazards due to the translocation and accumulation of these metals in the edible sections of cauliflower [5], [6]. A common concern to the public's health is heavy metal buildup in edible crops. Since vegetables make up a large portion of the average person's diet, their nutritional quality is of particular relevance. By identifying the exposure pathways to the target organisms, one may estimate the exposure level for a pollutant's potential health effects. The DIM data showed that eating plants cultivated in contaminated soils results in a higher dietary intake of metals than eating plants cultivated in unpolluted soils. The DIM readings from unpolluted plants were, in comparison to the polluted location, largely devoid of hazards for both adults and children for all estimated metals. The HRI for these metals, on the other hand, was 1, indicating that there were no adverse effects from plant transmission down the food chain and safe eating. While the HRI of these metals was greater than one, indicating hazards to consumers due to the presence of plants in high proportion in the diet of local populations and consequently have a higher risk to human health, eating contaminated cauliflower may cause health complications due to the high dietary intake of Pb, Cd, MN, Fe, and Ni grown in the polluted site.

As a result, eating contaminated cauliflower may also increase the risk to human health. A greater Cd and Pb concentration suggest possible dangers to human health from eating cauliflower. Reported a similar finding, stating that a high concentration of Cd with a high risk to human health accumulated in plant curd. In the contaminated farms growing the cauliflower crop, the soil chemical analysis showed high values for the majority of the variables, including salinity and heavy metals. The findings were congruent with these findings. Anthropogenic and industrial activities, as well as the excessive use of fertilizers on the polluted site, may be to blame for the elevated concentration of heavy metals. In addition, excessive pesticide and fertilizer use, manure made from combustion wastes, or the use of non-degradable municipal solid wastes could all be contributing factors to the high concentrations of Cd, Cu, and Cr found in soil samples. It is important to note that the majority of heavy metals that were examined, with the exception of Cr, Cu, and Ni in the contaminated site and Fe, Co, and V in the unpolluted site, were over the allowable limits (WHO/FAO, 2013). Furthermore, according to the PLI data, the polluted farms had Pb, Zn, Fe, Cu, and Cd contamination levels that were extremely high (PLI > 5), Cr, MN, Co, and V contamination levels that were moderate (PLI = 1-4), and Ni contamination levels that were low.

The mean plant density, stem length, root length, and number of leaves were nearly 1.5 times higher in the unpolluted than contaminated areas, according to the growth criteria of the cauliflower plants. Under pollution stress, all measured parameters showed a considerable decline. These outcomes were consistent with those of Kumar et al., who studied the same plant. This decrease may be the result of greater levels of heavy metals, particularly Pb, Ni, Fe, MN, Cu, Co, and Cr, accumulating in the various tissues of these plants. Many researchers have proven that heavy metals have a negative impact on plant growth parameters, particularly Pb and Cd, which significantly lower the number of leaves and stem and root length. The growth of plants is reportedly inhibited by Co and Cr ions in terms of shoot and root length, shoot and root fresh and dry weight, and leaf number. This may be accomplished by lowering photosynthetic pigments and photosynthetic activity, as well as by preventing cell division and elongation. The heavy metals-polluted site's cauliflower biomass and production were much lower, according to the current analysis. At the unpolluted farms, 42.3 t ha-1 of cauliflower curd were produced; at the polluted site, that production fell to 11.5 t ha-1.

In soil modified with heavy metal-rich sludge, measured 12.43 t ha-1 of cauliflower curd production, while measured 62.1 t ha-1 in a sandy freshwater-irrigated soil. The increased quantity of macronutrients and organic matter in the sludge, according to was the cause of this high yield. On the other hand, heavy metal-induced damage to leaf tissue and inhibition of chlorophyll synthesis may be to blame for the decreased biomass and curd production in polluted farms. As a result, the plant biomass and yield appeared to have decreased due to the low photosynthetic activity and slowed plant growth. In addition to the buildup of large amounts of heavy metals in the various plant components, heavy metal toxicity, according to Chatterjee and Chatterjee, reduces biomass, lowers Fe concentration, chlorophyll a and b levels, and lowers catalase activity in the leaves. Additionally, the decline in macronutrients, particularly N and P, in contaminated environments may potentially lower plant biomass and yield [7], [8].

Resources and Procedures

One liter of water samples was taken from the Bandar Canal of the Krishna River as it passed through the Penamaluru Mandal and placed in clean polyethylene bottles. The sample bottles were cleaned with sample water, dried, and pre-treated with weak nitric acid before being exposed to analysis. Average results are presented. Clean polythene bags were used to gather soil samples from six different locations on Penamaluru Mandal's irrigated farmlands. The samples were analyzed, and the results are presented as average values. The same locations where the soil samples were taken were also used to gather fresh cauliflower curds, which were then prewashed in distilled water to eliminate soil and dust particles. The samples were air dried before being analyzed with an ICP spectrometer that is fully automated, and the values were recorded.

Results

Nickel (Ni): According to Zig ham and Hassan et al, nickel is a crucial trace element for both human and animal health. Small amounts are required for lipid control; however, greater amounts are hazardous. Rocks, dirt, and industrial waste dissolve into nickel, which then finds its way into surface waters. Nickel concentrations in water samples range from 0.008 mg/l to 0.029 mg/l. Nickel levels in soil samples ranged from 30.6 mg/kg to 69.3 mg/kg, and at soil sample 4 it exceeded the allowable limits. Nickel was not present at any concentration in any of the cauliflower samples. This might be because nickel in vegetable plants doesn't accumulate.

Chromium (Cr): Vegetables and fruits naturally contain chromium. The primary sources of chromium in surface waters are chemical companies. Chromium levels range from 1.32 mg/l to 2.88 mg/l and are all above the allowable limits in all of the water samples. The range of chromium concentrations in the soil samples, from 88.32 mg/kg to 139.99 mg/kg, is above the allowed limits. Two samples of cauliflower taken from sites 3 and 4 had values (4.199 mg/kg and 6.321 mg/kg) that were over the allowable limits. Chromium is a compound that is extremely bio-magnetizable in plants. Its ability to fight illnesses is decreased at high doses.

Cadmium (Cd): Pesticides and manures are the main ways that cadmium (Cd) enters the environment. The main sources of cadmium in surface waterways are household and industrial wastes. Cadmium is highly harmful since it strongly binds to organic stuff in soils and will accumulate through food consumption. Cadmium concentrations in all of the water samples ranging from 0.034 mg/l to 0.151 mg/l are higher than the allowable limits. All of the soil samples had cadmium concentrations that ranged from 3.28 mg/kg to 5.86 mg/kg that were higher than allowed. All of the cauliflower samples that were taken revealed higher than allowed cadmium amounts.

Copper (Cu): Human and natural activities like garbage disposal and phosphate fertilizer production introduce copper into the environment. Due to the fact that copper does not decompose in the environment, it can accumulate in plants and animals through soils. The concentrations of copper, which range from 0.093 mg/l to 0.25 mg/l, are all beyond the allowed limits and accumulate in the liver and brain of humans. The range of copper concentrations in the soil samples, from 143.2 mg/kg to 166.3 mg/kg, is above the allowed limits. Samples of cauliflower taken at location 4 revealed higher copper contents (39.19 mg/kg) than allowed limits.

Benzoyl (Pb): Environmental lead is a natural occurrence. However, lead in soil and surface waters is mostly a result of human activity, such as the burning of solid waste. In soil organisms and water bodies, lead builds up. Lead interventions disrupt soil functioning, particularly in areas close to roadways. Both individual organisms and the entire food chain can collect lead. Lead concentrations in all of the water samples ranging from 0.036

mg/l to 0.083 mg/l are higher than the allowable limits. Lead concentrations in soil samples, ranging from 256.3 mg/kg to 483.2 mg/kg, are higher than the permitted limits in three survey sites. Samples of cauliflower taken from sites 3 and 4 revealed copper contents that were higher than allowed 3.99 mg/kg and 4.62 mg/kg, respectively. The most prevalent element in the crust of the earth is iron (Fe). The main sources of iron in surface waterways are home and industrial wastes. The rate of your heartbeat quickly increases when you have too much iron. The range of iron concentrations in the water samples, from 0.391 mg/l to 0.94 mg/l, is above the allowable limits. The iron concentrations in the soil samples, which range from 26.83 mg/kg to 36.39 mg/kg, are all above the allowable limits. The samples of cauliflower taken from sites 1 and 2 revealed higher iron concentrations 269.32 mg/kg and 258.3 mg/kg than allowed limits.

Zn (zinc): A tiny element called zinc is crucial for maintaining human health. In physiological and metabolic processes, zinc is important. Natural sources of zinc include soil, water, and air. Zinc concentrations in water samples range from 2.39 mg/l to 3.96 mg/l. Zinc levels in the soil samples ranged from 201.3 mg/kg to 223.9 mg/kg and were within acceptable bounds. Zinc levels were lower in all of the cauliflower samples. To determine the extent of heavy metal contamination and its effects globally, several investigations were carried out. Specific field-level studies, which would cover a sizable area of agricultural land and generate a significant amount of pollutants, are either not displayed or are not available as references. The cost of data collecting and processing may be the cause of these practical issues. Heavy metal bio-accumulation in food chains via water and soil is a significant problem that needs to be addressed right now. Therefore, it was interesting to undertake a study to determine the amount of heavy metals present in the water, soil, and important seasonal vegetable crop, cauliflower, in the villages of Penamaluru Mandal in Vijayawada [9], [10].

In the current investigation, eight water samples were taken from irrigation canals along the Krishna River in Penamaluru Mandal villages. The study findings made it abundantly evident that the water had high levels of heavy metals like Cd, Cr, Fe, and Pb. The addition of municipal trash and industrial effluents from the city that discharge directly into the river may be the cause of its extreme values. This is in direct agreement with research that claimed residential pollution of many types and industrial effluent discharge were the main causes of the increase in heavy metal levels in waterways. The soil samples that were examined revealed elevated quantities of Cd, Cr, Fe, and Pb compared to the WHO/FAO-permitted levels. High levels of Cd, Cr, and Cu were found in soil samples in part as a result of farmers using excessive amounts of fertilizers and pesticides without being properly informed about how to apply them, and in part as a result of the usage of manure made from non-segregated municipal solid waste or combustion waste. Iron elements naturally present in soils, which is why soil samples had high quantities of Fe. Additionally, there may be high levels of lead because of farmlands that are close to national highways. High levels of Cd, Cr, Pb, and Fe have been found in some samples of cauliflower curds due to the bioaccumulation and biotransformation of these elements in plants from water and soil. These elements are likewise affected by and transferred to plants by slightly acidic pH levels in soil.

Scope

1. The extent of heavy metal uptake by cauliflower plants refers to the method by which cauliflower plants take in and store heavy metals from their surroundings. In soil, water, and the air are elements called heavy metals that are naturally present. Lead, cadmium, arsenic, mercury, and chromium are some examples of heavy metals that are frequently used.
2. As with other plants, cauliflower's roots have the ability to absorb heavy metals from the soil. The ingested florets of the plant may also be exposed to these heavy metals after they have been absorbed to other sections of the plant. The amount of heavy metals that cauliflower absorbs is influenced by a number of variables, including as the concentration of heavy metals in the soil, the pH of the soil, the length of exposure, and the particular qualities of the cauliflower type.
3. Heavy metals are present in cauliflower, which, if consumed in excess, could have negative health effects on people. As they build up in the body over time, toxic heavy metals can cause a number of different health problems. The amounts of heavy metals in agricultural systems must therefore be monitored and controlled in order to assure the safety of the food.
4. To reduce the uptake of heavy metals by cauliflower and other crops, regulatory bodies, farmers, and researchers work together. This entails putting into practice soil management techniques to lessen heavy metal pollution, such as utilizing clean water for irrigation, avoiding contaminated fertilizers, and evaluating the soil for heavy metal concentrations. The development of cauliflower variants with lower heavy metal absorption capacities is also being investigated using genetic engineering and breeding methods.
5. It's important to keep in mind that cauliflower is not the only plant that has a heavy metal absorption of this magnitude. The ability to absorb heavy metals to varied degrees also exists in a wide variety of other plants,

including cereals, root vegetables, and leafy greens. Important actions must be taken to assure food safety and preserve human health, including regulating heavy metal contamination in agricultural systems.

III. CONCLUSION

The polluted farms were highly polluted with Pb, Zn, Fe, Cu, and Cd; moderately polluted with Cr, MN, Co, and V; and unpolluted with Ni. The PLI of the calculated heavy metals (apart from Ni) surpassed one. Heavy metals like Cr, Co, Cu, Fe, Pb, and V have accumulated in the edible sections of cauliflower as a result of irrigation with heavy metals-contaminated wastewater, placing the general public's health at danger. The high concentrations of heavy metals in the contaminated soil had a negative impact on the development and yield of cauliflower. Since cauliflower showed high BF of the majority of predicted metals apart from Cr, Co, Cu, Fe, Pb, and V and low TF for these metals, it is a potential plant for Phyto stabilization.

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