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Bioaccumulation of heavy metals in mulberry sericulture: Review

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Abstract
Heavy metals take route to higher trophic levels by first of all accumulating in harvestable parts of plants like leaves. Higher the trophic level the amount of metal increase and affect every higher trophic level. Silkworm (*Bombyx mori*) is used as template to assess the biotransformation of heavy metal in a food chain from soil to mulberry plant then insect. The mulberry plants were irrigated with synthetic effluent of Cr, Co, Pb, Zn (100mg/L with pH 4.5) and the treated soil, mulberry plant leaves, silkworm body, and their excreta were sampled to check Cr, Co, Pb, Zn, contents accumulated by using atomic absorption spectrometry (AAS). The concentration of heavy metals in soil and mulberry leaves tend to increase with increase in irrigation times. On the other hand, the contents of Cr, Co, Pb, Zn in *B. mori* larvae and the excreta were in considerable amount but decrease with the increase in larval instars. The heavy metals found in *B. mori* body was liable for toxic effects on its life cycle and the body growth and silk production was also inhibited under the effect of Cr, Co, Pb, Zn accumulation. A considerable amount of heavy metals was also found deposited in the *silk glands, cuticle* and *alimentary canal,* and concentration of heavy metals in larval body increased *B. mori* and death rate also by significantly.

Keywords: triclosan, TCS, determination, detection, sensor

Introduction
Heavy metals are metallic; naturally occurring compounds that have a very high density compared to other metals at least five times the density of water. Heavy metals are toxic to humans. Some heavy metals are either essential nutrients (typically iron, cobalt, and zinc), or relatively harmless (such as ruthenium, silver, and indium), but can be toxic in larger amounts or certain forms. Other heavy metals, such as cadmium, mercury, and lead, are highly poisonous. Potential sources of heavy metal poisoning include mining, tailings, industrial wastes, agricultural runoff, occupational exposure, paints and treated timber.
Lead it is high density and ability to absorb harmful radiation; lead has been taken out of use in many products. Lead is a soft, silver colored heavy metal naturally found in the Earth. It is toxic to humans and builds up in the body over time. Lead is used mostly in large batteries, as shields for X-rays, or insulation for radioactive material.
Copper is the penny jar on the counter catches your eye. It is reddish brown heavy metal, Copper is still one of the best conductors of electricity and heat, and many electrical wires are made of copper and coated in plastic. Acute copper poisoning is rare, but like lead it can build up in the tissues, eventually leading to toxicity.
Mercury is a unique heavy metal, as it is liquid at room temperature and sometimes referred to as '*quicksilver*' The workers frequently came down with mercurial disease, characterized by tremors and the mental instability that created the nickname 'Mad-Hatter disease.' Mercury is toxic in any form and can even be absorbed through the skin.
Mulberry belongs to the genus Morus of the Moraceae family. Although it is extensively grown as food for silkworms in many countries, the mulberry fruit production is the main aim in Turkey, which is one of the most important mulberry fruit producers in the world. Mulberry is found from temperate to subtropical regions of the northern hemisphere to the tropics of the southern hemisphere and it can grow in a wide range of climatic, topographical and soil conditions. It is widely spread throughout all regions from the tropics to the subartic areas. Genus Morus is widespread in Asia, Europe, North and South America and Africa as well. Mulberry has a unique delicious fruit of the sour and refreshing taste. It has been used as a folk remedy to treat oral and dental diseases, diabetes, hypertension, arthritis and anemia. The bright black and purple mulberry fruits, which have a very pleasant taste when eaten fresh, are

also used in jams, juices, liquors, natural dyes, as well as in the cosmetics industry. Morus species are deciduous and in the period of low temperatures during the winter they are required to break dormancy. Mulberry fruits may be of white, red or black colour when they are ripe. Deep coloured fruits are good sources of phenolics including flavonoids, anthocyanins and carotenoids, and mulberries are rich in phenolics. Fruits and their extracts deserve special attention because of the important influence they have on human health. For the majority of the world population, fruits represent the primary source of the health care. Although the effectiveness of fruits is mainly associated with their constituents such as essential oils, vitamins, glycosides, etc., it was found that a prolonged intake can cause health problems due to the possible presence of heavy metals. Mulberry fruit and leaves (*Morus alba* L. and *Morus nigra* L.) from rural southeast Serbia were analyzed. Metals uptake from soil to leaves and fruit was determined. The health risk index estimates the risk due to the exposure.

Heavy metals in agriculture crops

Khan *et al.*, (2013) concluded that concentrations of heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni) and zinc (Zn) in agricultural soils and crops (fruits, grains and vegetable) and their possible human health risk in Swat District, northern Pakistan. Cd concentration was found higher than the limit (0.05 mg/kg) set by world health organization in 95% fruit and 100% vegetable samples. Moreover, the concentrations of Cr, Cu, Mn, Ni and Zn in the soils were shown significant correlations with those in the crops. The metal transfer factor (MTF) was found highest for Cd followed by Cr > Ni > Zn > Cu > Mn, while the health risk assessment revealed that there was no health risk for most of the heavy metals except Cd, which showed a high level of health risk index (HRI ⩾ 10E-1) that would pose a potential health risk to the consumers.

Heavy metals in mulberry and silkworm

Mulberry (*Morus indica* L.) belongs to the family moraceaea a fast growing, deciduous and perennial plant. It is the sole food plant of the silkworm (*Bombyx mori.* L) For silk production. Mulberry cultivation and silk production together comprises sericulture due to an ecofriendly, agro-based, labour intensive, rural cottage industry providing subsidiary employment and supplementing the income of rural farmers especially the economically weaker section of the society. Silk is one of most expensive fibers used in textile industry, produced naturally by silkworm (*Bombyx mori* L.) China along with India, South Korea, among these China and India are the major producers of natural silk, mulberry leaves are one of the key food sources for silkworms but some of the other plant leaves also proved experimentally (Nasreen *et al*., 1989) [13].

Silk is one of the most expensive fibers used in textile industry, produced naturally by silkworm (*B. mori*). Pakistan, China, India, South Korea are silk producing countries in that India is the major producers of natural silk. (Fernemore and Parkash, 1992) [8]. Mulberry leaves is one of the key food sources for silk worms but some of the other plant leave also proved experimentally good as peepal (Nasreen *et al*., 1989) [13]. All over the sub-tropical, tropical and temperate regions Mulberry tree are grown is a deciduous, deep-rooted fast growing, perennial tree. At present heavy metal contamination is effecting the growth as its root system supports the heavy metal uptake from the soil and deposits in the leave parts, which are the most preferred source of food for silk worm.

As the heavy metals are mixture of many enzymes and proteins so they are considered as essential and decisive for normal development of plant. Toxicity, inhibition of growth and reduce in yield of plants is caused by increase in amount of both essential and non-essential heavy metals in the soil (Costa and Morel, 1993) [7]. Use of mineral fertilizers, pesticides, sewage sludge application and anthropogenic source that as the smelting industry, mining, are the main source from where much higher amount is obtain (Michael *et al.*, 2007) [11]. In that Chromium is one of the well-known heavy metal, having significant impacts as proved toxic for agronomic crops (Ghosh and Singh, 2005) [9].

Keeping this review, the bioaccumulation of heavy metals in mulberry and its effect on silkworm will be discussed.

Bioaccumulation of heavy metals in soil (Mulberry field)

Peltier *et al.*, (2003) [16] concluded the mulberry plants were grown in soil irrigated with synthetic effluents whose pH varied from 4 to 6 and Zn (II) initial concentration ranged from 25 to 400 mg/l. The concentration of Zn (II) in soil before irrigation using synthetic effluent was 15.56 ± 0.01 mg/kg. Results of total Zn (II) concentration in soil after irrigation using synthetic effluent at different pH and concentration. pH and initial Zn (II) concentration were already found as important parameter in metal entrance to food chain. The concentration of Zn (II) in soil irrigated with synthetic effluents of different pH was determined with an interval of 15 days up to a maximum of 75 days. The synthetic effluents irrigation was managed on daily basis. The Zn (II) concentration in soil increased with the increase in pH and maximum up to 75 days. The concentration of Zn (II) in soil after 75 days of irrigation with synthetic effluents was found to be 386.51 ± 0.03 mg/Kg at pH 6.

The soil, in which mulberry plants were planted, was irrigated with Co (II) synthetic effluents with pH ranging from 3 to 5 and with initial Co (II) concentrations ranging from 25 to 400 mg/L. The concentration of cobalt in soil before irrigation using wastewater was 8.45-0.02 mg/kg. After irrigating soil using wastewater, the concentration of Co (II) in soil increased significantly. The maximum amount of Co(II) reside in soil at pH 4 and 400 mg/L initial concentration in synthetic wastewater. It was found that the Co (II) contents in soil were increased with increase concentration of Co (II) effluents. It reached to its maximum value of 273.5-0.04 mg/kg at the highest concentration of 400 mg/L after 75 days of irrigation. Increasing concentration effect was also observed by Perez-Espinosa *et al.*, (2005) [17]. The lowest Co (II) contents were recorded to be 59.5-0.01 mg/kg at 25 mg/L dose rate after the same time period. The Co (II) contents in soil were also increased with the increase in pH and were maximum (206-0.04 mg/kg) at pH 4 and minimum (19.5-0.01 mg/kg) at pH 3 after 75 days.

Nasir *et al.*, (2007) [12] reported the lead in soil results obtained clearly showed that the amount of Pb (II) deposited in soil by synthetic effluents was strongly dependent on effluent pH and effluent Pb (II) concentration. The highest deposited amount of lead was found to be 326.5-0.04 mg/kg at pH 5 and initial lead concentration of 400 mg liter. Widely spread lead is leading toxic heavy metal to living organisms. Ozer *et al.* (1994) found that the main lead contamination source were sugar finishing industries, automobile batteries, pigments for printing processes, etc. Results of this study clearly showed that lead concentration was much higher in soil irrigated using lead-containing effluent in comparison to the control soil sample. Lead precipitation occurred after pH 5. It is suggested that effluent pH should be increased >5 to cause Pb (II) precipitation from the effluent used for irrigation.

S. K. Abbas *et al.*, (2012) [2] reported that the mulberry plants were grown in different plots. These plots were irrigated with synthetic effluents having pH variation from 3 to 5. Cr (III) initial concentration ranged from 25 to 200 mg/L. The concentration of Cr (III) in soil before synthetic effluent irrigation was 15.56 ± 0.01 mg/kg. The amount of Cr (III) concentration observed in soil samples taken from the plots irrigated with synthetic effluent having different pH and concentrations of Cr-III are given. The concentration of Cr (III) in soil irrigated with synthetic effluents of different pH was observed with an interval of 15 days up to a maximum of 75 days. The plants were irrigated with synthetic effluents on weekly basis. The residues of Cr (III) were more in soil samples which irrigated with higher concentration of synthetic effluents. Residues of Cr (III) were also increased with the increase in post application duration. The Cr (III) concentration in soil was increased with the increase in pH and maximum up to 75 days. The concentration of Cr (III) in soil after 75 days of irrigation with synthetic effluents was noted to be 99.89± 1.02mg/Kg at pH 5. The Cr (III) concentration in soil was increased with increase in concentration of Cr (III) in synthetic effluents.

Heavy metals (Co, Cr, Zn, Pb, Cd, Mn, Cu and Ni) concentration of soil samples showed a variation depending on the distances from the roadside (from 20 to 1000 m) in the mulberry cultivated area. It was observed that the motor traffic activity of roadsides increased all of the metal content, especially Co, Cr, Pb, Cd and Ni in the soil. There were statistically significant differences between the distances in respect of total element concentration. The available and total Mn, Zn, Cu, Co, Cr, Pb, Cd and Ni contents of the soil near to road side (20-100 m) were considerably higher than samples taken farther away from the road side (> 400 m). Available form heavy metals in the soil were determined between 2.48-1.1 mg kg-1 Zn, 105.8-38.2 mg kg-1 Mn, 4.14-1.72 mg kg-1 Cu, 1.48-0.37 mg kg-1 Co, 0.05-0.02 mg kg-1 Cr, 3.89-1.09 mg kg-1 Pb, 0.05-0.02 Cd and 0.66-0.33 mg kg-1 Ni, while total heavy metal in the soil varied from 330.7 to 295.4 mg kg-1 for Zn, 527.3 to 436.8 mg kg-1 for Mn, 217.5 to 184.7 mg kg-1 for Cu, 11.4 to 7.95 mg kg-1 for Co, 48.3 to 33.69 mg kg-1 for Cr, 500.2 to 76.6 mg kg-1 for Pb, 4.24 to 1.73 mg kg-1 for Cd, and 26.45 to 16.96 mg kg-1 for Ni Pehluvan *et al.*, (2012) [14].

Bioaccumulation of heavy metals in mulberry plant

Prince *et al.*, (2001) [18] concluded that Pb (II) Contents in *M. alba*. The concentration of lead detected in the *M. alba* leaves at various time intervals is presented. *M. alba* was not a hyper accumulator plant because Pb (II) concentration was 1,000 mg/kg. The amount of Pb (II) accumulated in *M. alba* leaves was found to be 50 mg/kg for all treatments. The results obtained were in accordance with the previous findings. Prince *et al.*, (2001) [18]. Used the mulberry-silkworm food chain as a template to assess Cd and Cu mobility in terrestrial ecosystems. Bioaccumulation of lead by different plants is reported in the literature. The results of the referenced studies clearly showed that Pb (II) hyper accumulator plant biomass should be disposed of carefully to avoid Pb (II) transfer to the food chain. The maximum Pb (II) amount detected in mulberry plants was 42.78-0.02 mg/kg.

Mulberry was found to be Co (II) non-hyper accumulator plant the maximum amount of Co (II) bioaccumulated in mulberry leaves was 42.8-0.01 mg/kg at 400 mg/L cobalt initial concentration in wastewater. When the initial Co (II) concentration was low, the Co (II) bioaccumulation in mulberry leaves was also reduced. The lowest Co (II) contents in mulberry leaves were 15.45-0.02 mg/kg at 25 mg/L Co (II) in wastewater. These results are reported after 75 days micro plot experiment. Wastewater pH was also found to be important parameter in Co (II) uptake. The maximum bioaccumulation of Co (II) in mulberry leaves occurred at a soil pH of 4.5. The entrance of high concentrations of Co (II) in mulberry suggest that it could be a source of danger for animal and human life. The plant biomass present in highly polluted areas should be carefully disposed of to reduce the risk of severe damage to life and ecosystem. The accumulation of Co (II) in other plants was studied by previous researchers. They observed significant effect of Co (II) on plant growth by Prince *et al*., (2002) [19-20].

The Zn (II) concentration was determined only in mulberry leaves as it is the source of Zn (II) transfer to *B. mori* population. In general, the Zn (II) concentration in mulberry leaves increased with the increase in Zn (II) concentration in synthetic effluents. The maximum Zn (II) concentration accumulated in leaves was 142.85 ± 0.001 mg/kg. The same type of results, in case of Zn (II) accumulation by *Chromolaena odorata* was reported by Tanhan *et al.,* (2007) [22]. The results of this study indicated that the concentration of Zn (II) mulberry leaves decreased with increase in pH of synthetic effluents. From the results of this experiment, it can be suggested that the bioavailability of Zn (II) can be reduced by increasing the pH of effluents being used for irrigation. The accumulation of metals in vegetation is found to be problematic from a bioaccumulation stand point by Peltier *et al*., (2003) [16].

Peltier *et al*., (2008) [15]. Ashfaq *et al*., (2009a) [4] reported that the Cr (III) concentration was observed only in the leaves of mulberry plant. The leaves were a source of Cr (III) transfer to larvae of *B. mori*. The results of this study indicate that the concentration of Cr (III) in leaves of mulberry was increased with increase in concentration and pH of synthetic effluents. From the results of this experiment, it can be suggested that the bioavailability of Cr (III) can be reduced by decreasing the pH of effluents being used for irrigation at certain limit. The accumulation of metals in vegetation was found to be problematic for organisms of higher trophic level.

The mulberry plants were irrigated with synthetic effluent of Cr (VI) (100mg/L with pH 4.5) and the treated soil, mulberry plant leaves, silkworm body, cuticle, alimentary canal, silk glands, silk cocoons and their excreta were sampled to check Cr (VI) contents accumulated by using atomic absorption spectrometry (AAS). The results shows concentration of Cr (VI) found in B. mori body was obliged for toxic effects on its life cycle and the body growth and silk production was also inhibited under the effect of Cr (VI) accumulation.

In Mulberry leaves and fruits

Turan *et al*., (2012) [14] reported that the concentrations of heavy metal levels in the mulberry leaves and fruits from different distances from the road are summarized. In the leaves, the heavy metals concentrations ranged from 18.55-23.88 mg kg-1 for Zn, 234.0-354.4 mg kg-1 for Mn, 6.38-8.26 mg kg-1 for Cu, 0.24-0.72 mg kg-1 for Co, 0.28-0.61 mg kg-1 for Cr, 0.86-1.28 mg kg-1 for Pb, 0.03-0.06 mg kg-1 for Cd and 0.92-2.02 mg kg-1 for Ni, while the concentration of the heavy metal in the fruits varied from 5.97 to 8.74 mg kg-1 for Zn, 74.1 to 127.2 mg kg-1 for Mn, 2.12 to 3.14 mg kg-1 for Cu, 0.08 to 0.26 mg kg-1 for Co, 0.09 to 0.23 mg kg-1 for Cr, 0.28 to 0.47 mg kg-1 for Pb, 0.01 to 0.02 mg kg-1 for Cd and 0.3 to 0.75 mg kg-1 for Ni. The heavy metals in the mulberry leaves and fruits, as in the soil samples, were detected their highest levels at a distance of 20 m from the roadside.

Relationships between soil heavy metals content and mulberry plants (Fruits)

Pehluvan *et al.,* (2012) [14] concluded that the relationships between the heavy metal contents of soil and mulberry fruits at different distances from the road are illustrated. The correlation analysis showed a strong relationship between heavy metal (available form) concentration in soil and in mulberry fruit, particularly for Co, Cr, Zn, Pb, Mn, Cu and Ni. A significant correlation was found between mulberry cultivated soil and mulberry fruits in terms of Zn, Pb and Cu concentration at a distance of 20 m from the road. However, the correlation between soil and fruit samples for all heavy metals at a distance of 100 m from the road was non-significant. A strong relationship was also detected between soil and fruits in terms of Co, Pb and Mn concentrations at a distance of 400 m from the road and Cr, Pb, Mn, Cu, Ni and B concentrations at a distance of 1000 m from the road. Accordingly, some heavy metal available forms were highly expressed in mulberry trees and their fruits along the road side, except for a distance of 100 m, in soils.

In silkworm (*Bombyx mori* L.)

Bombyx mori

Pb (II) contents in *B. mori* body were determined by feeding larvae with Pb (II)-polluted mulberry leaves. The Pb (II) contents in *B. mori* larvae and its feces increased with increase in soil pH and Pb (II) initial concentration in synthetic effluent. The transport of heavy metal into the food chain of the insect population was also a topic of concern in the past Hafeez *et al.,* (2000) [10] determined the impact of industrial effluents on the population dynamics of aquatic insects.

Co (II) bioaccumulation in the larval body was maximum (31.2-0.02 mg/kg and 28.3-0.03 mg/kg) at 400 mg/L Co (II) concentration and soil pH 4.5. The lowest values were 11.7-0.01 mg/kg and 16.5-0.02 mg/kg at 25 mg/L and soil pH 3 after the completion of 5th larval instar. The life cycle of silk worm consist of five instars. The life span of 1st, 2nd, 3rd, 4th and 5th silkworm instars is of 2-3, 4-5, 6-7, 6-7 and 4-6 days, respectively. A detailed review of literature was made to study bioaccumulation of Co (II) in insects. But according to the information of the authors there was not a single study carried out in this regard. However accumulation of other heavy metals in insects is reported by many researchers Prince *et al., (*2002) [19-20].

Blackmore and Wang, *et al.,* (2004) [6, 23-24] *B. mori* accumulated different amounts of Zn (II) in body at different treatment levels given to soil at which mulberry plants were grown. The Zn (II) burdens in *B. mori* body were higher in treated soils than controlled ones. Zn (II) bioaccumulation in *B. mori* body was higher (91.375 ± 0.019 mg/kg) at low pH and high initial metal concentration of soil at which mulberry plants were grown.

Ashfaq *et al*., (2009*b*) [3] concluded the bio-transportation of Cr (III) to *Bombyx mori* from *Morus alba* leaves at different soil pH values whereas describe the effect of Cr (III) concentration in soil on its Bio-transportation to *Bombyx mori* from *Morus alba*. The Cr (III) amount in *B. mori* body was higher in treated soils than controlled one. Cr (III) bioaccumulation in *B. mori* body was higher (61.32 ± 0.036 mg/kg) at high pH and high initial metal concentration of soil at which mulberry plants were grown. Some other research workers studied Cd accumulation in silkworm larvae.

Growth as well as development and mortality of *Bombyx mori*

B. mori body length, body weight and mortality rates were significantly affected by Zn (II) concentration in larval body. Control larvae were found to have more body length and body weight and less mortality rate in comparison to those larvae that accumulated Zn (II) into their bodies. Spurgeon *et al.* (2000) [21].

Senthilkumar P *et al., (*2002) [19-20] reported the body length and body weight of silkworm (*B. mori* L.) were reduced with increase in Co (II) concentration. This suggested that increasing Co (II) concentration in silkworm body weakened the silkworm larvae. And subsequently the mortality rate of silkworm was also increased. The results are presented. The toxicity of different heavy metals in various insects was studied by many researchers in the past. From the obtained results it can be easily concluded that silkworm larvae can be used as a useful template to access localized Co pollution in terrestrial ecosystems by observing changes in its normal life cycle.

Wang *et al.*, (2004) [6, 23-24] determined the impact of industrial effluents on the population dynamics of aquatic insects. They concluded that the aquatic insect species can be used as tool to access the pollution of the aquatic ecosystem. *B. mori* body length, body weight, and mortality rate were significantly affected by presence of Pb (II) in its body. Maximum reduction in silkworm body length and body weight was up to 19.3 and 20.1%, respectively, whereas maximum morality rate in silkworm larvae was observed to be 41.2%. Wang *et al.,* (2004) [6, 23-24] evaluated the toxic effect of Cd on mulberry and silkworms. They found that higher Cd level reduced mulberry leaf yield. Ingestive and digestive rates of silkworm larvae were also significantly affected by the presence of Cd in mulberry leaves.

Ali *et al.,* (2009) [1] reported that *B. mori* body length and body weights were significantly reduced by Cr (III) concentration in larval body and mortality rate increased. Control larvae showed more body length and body weight and less mortality rate in comparison to those larvae that accumulated Cr (III) into their bodies. Some other research workers also noted negative impact of heavy metal accumulation on larval growth of silkworm larvae. Tucker *et al*. (2004) [23] reported same kind of effects of Cr (III) on silkworm larvae.

Silk glands of *Bombyx mori*

The accumulation of Cr (III) silk glands are shown at different concentration levels and pH. Increasing trend in the accumulation of Cr (III) silk glands was found as the concentration and pH of the effluent applied increased. The maximum of accumulation of Cr (III) was found when the concentration applied was 200 mg/kg and its value was noted as 6.5 ± 0.019 mg/kg.

Conclusions

From this topic, Cr (III) has been concluded that *B. mori* excreted large quantity of Cr (III) but still most of Cr (III) remained inside its body. The symptoms of Cr toxicity appeared as severe wilting and chlorosis of plants. The synthetic effluents irrigation was managed on weekly basis. This study suggested that heavy metals accumulation imposed negative impacts on larval growth of silkworm larvae. These conclusions clearly suggested that Cr (III) presence in aqueous effluents used for plant irrigation. The bioaccumulation of Co (II) in soil, mulberry plants, silkworm larvae and body length, body weight, and mortality was maximum at the initial Co concentration of 400 mg/L. Bioaccumulation of Co (II) in the larval bodies of silkworm was significantly increased when they were feed upon Co polluted mulberry leaves. Although silkworm (*B. mori* L.) larvae excreted large quantity of Co (II) in its faeces, still a large amount of Co (II) remained in its body. The Co (II) conclusion that presence in aqueous effluents used for plant irrigation should be strictly monitored to avoid ecological pollution. The Zn (II) concentration is concluded in soil after irrigating it with metal contaminated water. The mulberry plants appeared to scavenge and accumulate Zn (II) into its leaves, allowing for its potential transfer and bioaccumulation in higher tropical level organisms. Although in *B. mori* excreted large quantity of Zn (II) but still most of Zn (II) settled inside its body. These results are clearly suggested that Zn (II) presence in aqueous effluents used for plant irrigation. *Morus alba*, although not a hyper accumulation plant, but still has the ability to accumulate and transport Pb (II) to B. mori. Thus, the mulberry-silkworm food chain can be used to monitor Pb (II) movement in the terrestrial ecosystem. Pb (II) magnification occurred in the silkworm body, and it was found to be a very toxic metal for silkworm even in low concentrations. Pb (II) accumulation was higher at soil pH 5 and 400 mg/liter initial concentration of Pb (II) in wastewater.

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