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Chapter- 16

A Review on the Impact of Chromium Toxicity in Crab

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Keywords: Chromium toxicity, Crab, Heavy metals, Bioaccumulation.

Abstract:

Crabs, an important edible crustacean of coastal ecosystems are subjected to heavy metal accumulation, particularly chromium as a result of environmental pollution and other anthropogenic activities. Chromium has been sourced from natural processes and industrial activities, bioaccumulates in crab tissues, posing risks to both the organism and consumers. Various studies indicate differential tissue accumulation and histological alterations in vital organs of crab, mainly, hepatopancreas, gills, and muscle being primary targets. High chromium concentrations induce histopathological changes, impacting tissue integrity and physiological functions. As a result of chromium toxicity crab's behaviour is also affected, manifested as hyperactivity, aggression, and impaired motor coordination. Understanding about the impact of chromium on crab physiology and behaviour contributes to mitigate its environmental consequences and ensuring the sustainability of coastal ecosystems. This review underscores the urgent need to monitor heavy metal levels in crab populations to safeguard both ecological health and human consumers.

Introduction:

Crabs are considered the most interesting groups among decapod crustaceans used as test animals for laboratory research (Heasman and Fielder, 1983). They are distributed in seas, backwaters, estuaries, lakes, and freshwaters (Balasubramanayan, 1962; Bairagi, 1995; Bhadra, 1995; Dev Roy and Rath, 2017, Dev Roy and Nandi, 2007; Dev Roy and Bhadra, 2008). Because of their high protein and mineral content, crabs are not only nutritious but also a superior source of income for the people residing in coastal areas (Dhanya Viswam, 2015; Nanda et. al. 2021). Being exposed to tidal water and coastal lands alternately, crabs are

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regularly exposed to different pollutants of water as well as pressures from terrestrial environments. On the other hand, the discharge of the wastes without adequate treatment often contaminates the water bodies with conservative pollutants (like heavy metals), many of which accumulated in the tissues of resident organisms like fishes, oysters, crabs, shrimps, and seaweeds among others (Iyengar, 1991; Shou Zhao et al. 2012; Das et. al., 2015; Fisayo et al. 2017), thus produce toxicity in these organisms. Hence, it is important to investigate the levels of heavy metals in crab to assess whether the concentration is within the permissible level and possibly may pose any hazard to the consumers (Krishnamurti and Nair, 1999; Sivaperumal et al., 2007; Uysal et al., 2008; Palaniappan and Karthikeyan, 2009). On the other hand due to urbanization, industrialization and advanced agriculture practices, heavy metals, pesticides, insecticides and other pollutants are regularly disposed in the water bodies and thus warrant in-depth research to save the diversity of crab species.

Due to their toxicity, long persistence, bio-accumulative, bio-magnifying and non-biodegradable properties in the food chain, metals constitute a core group of aquatic pollutants (Tchounwou et al., 2012; Pandiyan et al. 2021). They occur in the environment both as a result of natural processes and as pollutants from human activities (Garcia-Montelongo et al. 1994; Jordao et al. 2002). Once discharged into water bodies metals can either be adsorbed on sediment particles or be accumulated in aquatic organisms. It was evident that concentrations of metal in aquatic ecosystems have also increased due to mining, industrial, and agricultural activities (Ikem and Egiebor, 2005; Uysal et al., 2008).

In general, crustaceans have higher sensitivity towards heavy metals (Migliore and De Nicola Giudici, 1990). Previous studies revealed that bottom feeder crabs are expected to concentrate more heavy metals in their body parts than the surface feeders (Bastami et al., 2012). Frequent fluctuations of ambient salinity could be a major cause of bioaccumulation of metal in the estuarine crab (Zanders and Rojas, 1996). Several studies revealed that accumulation of heavy metals in crab begins when they are present with high concentrations in surrounding medium (Hosseini et al., 2014; Fatemi and Khoramnejadian, 2016).

Chromium (Cr) is an important heavy metal having atomic number 24. Chromium can exists in different oxidation states among which Chromium (VI) is most significant for its stability and persistence. Chromium (VI) is one of the most hazardous heavy metal released from industries like electroplating, leather tanning, dye production, wood preservation, stainless steel welding etc. (Das and Mishra, 2009; Madhu et al., 2022). Despite its essential role in biological systems, excessive amounts of Cr can lead to toxic effects (Bielicka-Gieldonet al., 2005). It is evident that Cr accumulation in tissue can create histological alternation of different organs like the gills, hepatopancreas, and muscles of crab species (Vasanthi et al., 2014). Some important enzymatic activities are also affected by sub-lethal concentrations of Cr. The present review deals with the impacts of high concentrations of Cr on crab, where the authors are concerned as the direct consumers of crab and crab products.

Source and transport of chromium in the environment

Cr occurs as a natural component of the Earth’s crust (Sneddon, 2012; Srivastav et al., 2018). It exists in several oxidized forms in the environment of them the most stable and common form is Cr (o) (e.g., elemental metallic chromium), which only exists in ores essentially chromite; Cr (III), e.g., ferrochrome ($FeCr_2O_4$) or chromate; and Cr (VI) species, e.g., ammonium dichromate $[(NH4)_2Cr_2O_7]$. Cr (III) is released from weathering and readily adsorbed by clay minerals and precipitates with iron and aluminum hydroxides. The concentration of Cr in the environment is also increased due to anthropogenic activities (Prasad et al., 2021). Various industrial applications such as production processing of metals, chrome, chromate, leathers, textile, chrome plating, stainless steel welding, steel slags, and ferrochrome pigments are extensively used Cr (Bielicka-Gieldon, 2005). Cr is released into the environment through these industrial sources, particularly from the processing and manufacturing of chemicals, minerals, steel, metal plating, leather tanning, textile dyeing, electroplating, cement production, metallurgical works, and other industrial processes (Nakkeeran et al., 2018; Lian et al., 2019). Large amounts of wastewater, including solid sludge and Cr-bearing waste, such as tannery effluents, are also generated from these industrial activities, which contribute to significant chromium pollution worldwide (Yoshinaga et al., 2018). Cr is transported in the environment primarily through weathering of rock, atmosphere fallout, and wet and dry precipitation. It is reported that chromium is also washed out from the terrestrial systems (Sneddon, 2012). According to He and Li (2020) higher Cr concentration found in soil and rock samples, indicate that loess and mudstone are important sources of Cr (VI) pollution (He et al., 2020). Soil and water pollution can occur due to leaching and weathering of chromite from mines and infiltrated water (Das and Mishra, 2009). In India, Tamil Nadu (e.g., Ranipet), Uttar Pradesh (e.g., Kanpur), Odisha (e.g., Sukinda Valley), and West Bengal (e.g., Ranaghat-Fulia), are particularly at high risk from increased concentrations of chromium in soil and water (Shankar and Venkateswarlu, 2019). The following tables (Tables 1 and 2) depict about the types of hexavalent Cr and Cr-content in various industrial effluents.

Table 1: Type of hexavalent chromium [Cr (VI)] used in various industries (Das and Mishra, 2009)

Cr- used in industries	Chemical form
Anti-corrosion agent (chrome, spray coatings)	Barium chromate ($BaCrO_4$), Calcium chromate ($CaCrO_4$), Zinc chromate ($ZnCrO_4$), Strontium chromate ($SrCrO_4$), Sodium chromate ($CrNaO_4$)
Tanning of leather products	Ammonium dichromate [$(NH_4)_2Cr_2O_7$]
Wood-preservatives	Chromium trioxide (CrO_3)
Stainless Steel	Potassium chromate ($KCrO_4$), Sodium chromate ($CrNa_2O_4$), Ammonium dichromate [$(NH_4)_2Cr_2O_7$], Potassium dichromate ($K_2Cr_2O_7$)
Paints, inks, and plastics, pigments	Barium chromate ($BaCrO_4$), Calcium chromate ($CaCrO_4$), Lead chromate ($PbCrO_4$), Zinc chromate ($ZnCrO_4$), Potassium dichromate ($K_2Cr_2O_7$), Sodium chromate ($CrNa_2O_4$)

Table 2: Chromium content in various industrial effluents sources and wastewater release (Prasad et al., 2021)

Sl. No.	Industrial effluents and wastewater release	Cr content (mg L^{-1})	References
1.	Tannery effluents	0.7–345 mg L^{-1}	Dhungana and Yadav (2009)
2.	Chromite ore processing waste	199–3970 mg kg^{-1}	Becker et al. (2006)
3.	Textile mills effluents	0.11–0.21 mg L- 1	Bhardwaj et al. (2014)
4.	Chrome plating industry wastewater	5721.95 mg L- 1	Karega et al. (2015)
5.	Steel industry slags	2915 mg kg- 1	Sas et al. (2015)

Bioaccumulation of chromium in crab

Heavy metals released from natural and anthropogenic sources cause environmental pollution of aquatic ecosystem because of their bioaccumulation, long persistence and biomagnifications in the food chain (Erdogrul and Ates, 2006, Rainbow, 2007, Jakimska-Nagorska, 2011, Jitar et al., 2013). Crabs are benthic crustacean and because of their detritus and bottom-feeding habits crabs are more sensitive to bioaccumulation of metals (Basmati et al., 2012, Williams et al., 2022). Though Cr is an essential metal, the elevated concentrations of Cr are found in different crab species which can cause hazard (Rahman et al., 2019). The bioaccumulations of Cr in different tissues are mainly dependent upon water-metal concentrations and exposure time (Bochenek et al., 2008; Mansouri et al., 2011). Bioaccumulation of Cr also varies depending on size and type of tissues (Imad et al., 2022). As the organism's size and dimension increase, the concentration of Cr in soft tissues and the shell decreases substantially (Sharma et al., 2023). Different tissues show varying levels of Cr accumulation, with the highest concentrations found in gills, kidneys, and hepatopancreas, while less in muscular tissues (Kim and Kang, 2016). Williams et al., (2022) advocated that higher chromium concentrations in the muscle of crab from Ashtamudi lake, India. In blue swimmer crab from northern Bay of Bengal hepatopancreas was recorded with highest Cr concentration followed by gill and muscle (Das et al., 2015). Batvari et al. (2013) also recorded the distribution of total chromium concentrations in *Scyla serrata* in the following order: hepatopancreas > muscle > intestine > gills. Another report revealed that Cr levels in hepatopancreas, gills, muscle and whole body tissues of fresh water crab *Barytelphusaguerini* were high than maximum allowable standards in food (Sayyad et al., 2007).

Effects of chromium on tissue histology

High Cr concentration caused many histological alterations in crab tissues (Sharma et al., 2023). Hexavalent Cr caused invasive melanized cuticular lesions at the chelipeds and pleopods (Ranga Rao and Doughtie, 2003). Several structural changes like hyaline degeneration, splitting of muscle fibers, and appearance of granular materials are reported under TEM analysis in muscle tissue of *Scylla serrata* due to chromium toxicity (Williams et al., 2022). Structural alterations like atrophy, vacoualization were also observed in the muscle of mud crab by Lourduraj et al., 2014. Similar types of alterations in hepatopancreas, gills are also reported (Sanaa,2020).

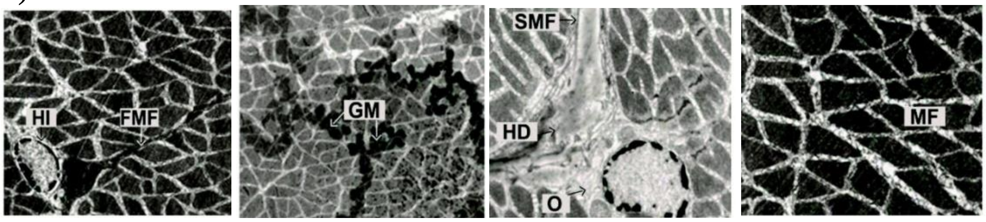

Figure 1. (MF – Myofibrils; SMF – Splitting of muscle fibres; HD – Hyaline degeneration; O – Oedema; GM –Granular materials; FMF – Fragmentation of muscle fibres in muscle tissue of S. serrata due to chromium toxicity (Williams et al., 2022)

Effects of chromium on body physiology

Though Cr is an essential nutrient, but hexavalent and trivalent chromium, can be toxic and even carcinogenic at high concentrations. Previous studies indicate that excess Cr affects the body's redox balance. As a results reactive oxygen species (ROS), are formed leading to reduction in antioxidant enzyme activity, and alterations in oxidative status (Rai et al., 2004; Dazy et al., 2008). Olmedo et al. (2016) reported alterations in haemocyte count and functions due to chromium toxicity in crabs. Crab haemolymph contains haemocytes, performing various functions like food transport, phagocytosis, capturing foreign particles, defense, and haemolymph coagulation.

Effects of chromium on behavior

There are very few reports on the effect of chromium on the behavior of crab. However, some behavioural anomalies such as hyperactivity, aggression, loss of balance, erratic swimming, rapid surfacing, profused mucous secretion, blackening of gills etc. are observed due to high concentrations of chromium (Sharma et al., 2008). Cr also appeared to cause labyrinth hypoactivity in the antennal glands (Williams et al., 2022).

Effects of reproduction

Acute exposure of female crabs (*Carcinus maenas*) to Cr caused a significant inhibition of ovarian alkaline phosphatese and non specific esterase activities, a significant reduction of ovarian protein content and decreases in both GSI (Gonadosomatic index) and HIS (Hepatosomatic index). In addition, crabs exposed to chromium showed a significant increase of acid phosphatase activity thus interfere with the ovarian cycle and therefore, with the reproduction of crab species (Elumalai et al., 2005).

Conclusion

It can be concluded that chromium contamination is imposing huge alterations in crab’s life though all the hazardous notations. This review can put forward the basic potential alterations of chromium pollution in crabs and will be helpful for future researchers to gather advanced knowledge of the ecotoxicology and risk assessment of chromium.

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