Heavy Metal Toxicity in Rice and its Effects on Human Health

Anjali Pateriya¹, Rohit Kumar Verma ², Mahipal Singh Sankhla ³*, Rajeev Kumar ⁴*

¹ Student of M.Sc. Food Technology, Institute of Food Technology, Bundelkhand University, Jhansi, India
² Student of B.Sc. (Hons.) Forensic Science, Department of Forensic Science, School of Basic and Applied Sciences, Galgotias University, Greater Noida, India
³ Research Scholar, Department of Forensic Science, School of Basic and Applied Sciences, Galgotias University, Greater Noida, India
⁴ Associate Professor, Department of Forensic Science, School of Basic and Applied Sciences, Galgotias University, Greater Noida, India
* Correspondence: mahipal4n6@gmail.com;
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Abstract: Nowadays, rice is the staple food grain of billions of people worldwide. The scientific name of rice is Oryza sativa L. There are four types of rice found in all over the world. Heavy metals, such as arsenic, cadmium, lead, iron, etc. are also found in rice, which causes harmful effects in the human body. Recently, rice has also been identified as a major exposure route. Rice is the most important grain concerning human nutrition and calorie intake, providing more than one-fifth calories consumed worldwide by humans. Acute toxic effects of rice are lower risk of heart disease, diabetes, possibly stroke, obesity, etc. and the side effects of rice are swelling around the drip site, hearing changes, liver changes, sore mouth, diarrhea, flushing of the face, changes in blood pressure, etc.

Keywords: rice, Oryza sativa L, acute toxic effects, calories, obesity, diabetes.

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1. Introduction

Rice, the main nourishment yield in numerous Asian areas, is now disposed to heavy metal injuriousness owing to the recurring practice of metal-enriched agro-chemicals, recurrent usage of excess water, and sewage mud (as organic alterations), which established ponds of heavy metals inside the topsoil [1]. In rice greeneries, we take revealed that NO counters oxidative anxiety encouraged by parquetry, lack of fluids, and polyethylene glycol [2,3]. Additionally, lately, we have exposed that the elevation of rice leaf senescence produced by abscisic acid, which persuades H₂O₂ making and lipid peroxidation, can be countered by NO givers [4]. In the current examination, we inspected the consequence of NO on Cd persuaded noxiousness of rice leaves. Rice is an extremely expanded crop, being full-grown from the equator to over 40° N after sea-level ca. 2,700 m in portions of the Himalayas and a wide environmental variety of agriculture schemes. Though there is abundant fewer biological differences originate inside its rough ancestor multifaceted (Oryza rufipogon and Oryza nivara), these are, however, dispersed ended a widespread physical variety and a range of environmental places from enduring to periodic marshes. As the origins of crop growing need which had established in residences where hunter–collectors were exploiting rough populaces, the circulation of the wild ancestor, in the history when agriculture started, is a key component in classifying the heritages of rice [5]. Throughout ages of drier weather, such as the Pleistocene
icy eras, we suppose that these wild inhabitants would devise stayed more limited into rainier steamy refugia, in portions of Eastern India, Yunnan, and inland Southeast Asia. This is reliable with the hereditary proof that the inherited haplotypes of O. rufipogon are originated in Southeast Asia and India [6]. The greatest current physical growth and radioactivity of rough rice people would have in progress ca. 15000 BP (16500 cal. BC) as postglacial climatic circumstances usual in. In addition to the vicissitudes in high temperature and rainfall rules, it must be well-known that this history is also mentioning an affected upsurge in impressive CO$_2$ levels from 18 Pa (atmospheric partial pressure) to 27 Pa, by 11000 BP. This is probable to have had a major influence on the photosynthetic efficiency and biomass construction of plants, but particularly C3 plants like rice [7,8]. We suppose this era to have observed the main development in the physical variety of rice near advanced latitudes, particularly in East Asia, where a northwards growth was not obstructed by the high Himalayas. We may likewise imagine approximately adaptive variations in rice morphology in reaction to new climatic and atmospheric situations and will reoccurrence underneath to in what way this influence confuse the gratitude of some domestication characters [9]. This had been noted that dissolved heavy metals concentration is more in the rise in environmental temperature as compared to cold weather. Heavy metal poisonousness has been established to be a major risk, and there are several health threats related to humans and animals. The toxic effects of these metals, even though they do not have any organic role, persist current in approximately or the other form damaging for the people's body and its suitable working [10].

2. Major sources of rice toxicity

Heavy metals from natural and anthropogenic causes collect in soil and flora and, as a significance, denote vital ecological pollution difficulties. However, food care problems and adverse vigor dangers create one of the greatest thoughtful ecological concerns [11].

2.1. Natural source.

Natural resources and human events such as quick industrial development, urbanization, and anthropogenic causes are major causes of heavy metal pollution, which are a disturbing danger to the surroundings and human condition [12]. It seems that the early cause of heavy metals in soils is the maternal components. The importance of maternal components in conclusive the metal content is specified to be prominent in soils, which formed from similar or only parental substantial such as igneous rocks (granite or basalt) or sedimentary rocks (sandstones, shales, limestones, dolomite) or undeveloped soils that have existed battered in moderate circumstances [13,14]. Though such studies are insufficient in India, with slight data on toxic heavy metal pollution of paddy meadows and danger valuation, rice is the supreme significant essential food for Indian populations. The objects of the current study, consequently, are chiefly danger valuation of latent poisonous and non-essential heavy metals - Cd, As, Pb, and Cr, in the external soil of paddy arenas at the mainly paddy-cultivated collection close Kalpakkam (Tamil Nadu). Concentrations of the poisonous heavy metals were evaluated in soil, root, shoot, and grains of paddy crops to measure the bioaccumulation influence and transmission influence. Hazard valuation was made evaluating the possible threat issue for the local inhabitants' overwhelming rice, the staple food [15]. However created from normal causes, the preparation and generous of maternal components, unit of living, the chemical,
biotic and somatic properties of soil, and the climatic conditions seem to have a rich result over
the attendance and supply of heavy metals in soils [16, 17].

2.2. Anthropogenic sources.

The metal concentrations in the rice testers differ mainly amongst the dissimilar studies,
which may be credited to the geology of the range, concentration of metals in the soil and
dampening water, and the anthropogenic undertakings of the area. Though, the metal
concentrations of the rice testers in the current study were in kind of the additional studies [18].
The human condition is straight affected by the complete consumption of crops full-grown in
contaminated soils. There is a rich indication that human renal dysfunction is associated with
the pollution of rice with Cd in existence farmhouses in Asia. Certainly, in Asia, rice has been
recognized as some of the chief sources of Cd and Pb for human existence [1, 19–21].
Moreover, the difference in anthropogenic productions, there are numerous collecting
structures in the peri-urban area, and approximately all crops are expended nearby. Diverse
cropping organizations can have altered influences on heavy metal acceptance from soil to
plant and consequently can principal to changed health dangers to inhabitants concluded food
chain [22-24].

2.3. Soil source.

Soil and crop adulteration can be a vital path by which these poisonous metals arrive in
the human body, causing related health syndromes. Human acquaintance with heavy metals
via the intake of polluted rice is of unusual anxiety in China since rice is the main staple
nutrition for the overall population. Rice consumption has been demonstrated to be a main
source of acquaintance to approximately poisonous pollutants like As, Cd, Pb, and MeHg [25-
29]. Soil containing heavy metals make from both natural and anthropogenic causes. Natural
causes are mostly recognized to be lithogenesis, weathering, erosion, and other geological
methods [30]. Anthropogenic sources include mining, industrialized happenings, traffic
releases, and cultivated events (mostly the usage of pesticides and chemical fertilizers) [31-
33].

3. Heavy metals found in rice

3.1. Arsenic.

Arsenic in groundwater is mostly mineral with arsenate, including about 50% of the
total [11]. Phosphate and arsenate are equivalents, showing related physicochemical actions in
soils, and contesting straight for similar sorption locations on soil element exteriors [34].
Arsenic is disreputable for its poisonousness, and, since of this, arithmetical data of 20 years
specified that the regular yield of rice grown on the As-contaminated paddy soil was 18% lower
than that of adjacent paddy soils. Rice flora might not raise on soils in the locality of the
excavation landfills. As concentration in approximately husked rice surpassed the hygienic
food standard (0.7 mg As kg”1). Increased rice production is needed for meeting the need for
overpopulation in Shaoxing since the arable land, which was only 250 m² per capita is
decreasing rapidly. Therefore, field experiments were conducted to establish measures for
reducing As toxicity to rice plants [12].
The accretion of arsenic in rice is observed as a freshly known disaster for South-East Asia, where rice is a staple food [35]. The condition of arsenic poisonousness in India is disturbing with information on severe well-being difficulties amongst the inhabitants of circumstances: West Bengal, Bihar, Assam, Chhattisgarh, etc. [36-38]. The influence of arsenic polluted irrigation water on the arsenic gratified in rice is particularly significant for the people. Rice is the staple food of widespread arsenic parts, and it is full-grown in a flooded (reduced) state where arsenic obtainability is high [39]. Most of the available rumors focused mostly on the acceptance and accretion of arsenic in the rice plant watered with arsenic-contaminated water and soil concluded green-house pot research [40-43]. Arsenic arrives humans and animals primarily by intake of polluted water and food. Arsenic types (i.e., inorganic arsenite and arsenate, methylated anionic species, volatile arsenic hydride, and organic arsenic) in nutrition were described as main ways to human contact [44].

3.2. Lead.

Lead (Pb) has been used globally from an early period for its ductility, resistance to corrosion, and low melting point. The contextual absorptions of Pb in unadulterated soil lie within the series of 10-50 ppm; though, in the soil with low-level pollution, Pb concentration can be probable to variety from 30 to 100 mg/kg [45,46]. The levels of Pb in soils that are toxic to plants and are not easy to evaluate. Though, it is usually decided that soil Pb concentration reaching from 100 to 500 ppm is measured to be extreme [47]. The poisonous indications of Pb in vegetables are not exact. Numerous studies consequence in the hindrance of plant development. The special inhibitory effects may be owing to interference with enzymes vital for usual metabolic and growth [48], photosynthetic processes [49], water, and inorganic nutrients fascination [50], and variations in cell ultrastructur [51]. For its contamination to plant, animal, and human being, Pb has freshly established much consideration as a main biochemical contaminant of surroundings. The captivation and conveyance of Pb by yields are of excessive anxiety, particularly its accretion in the comestible amount. The Pb content of plant full-grown on Pb-polluted parts is, overall, extremely connected with the Pb attentiveness in soil, though the association varies between organs of the plants [52, 53]. The uptake, transportation, and growth of Pb by plants are powerfully ruled by soil and plant tissues, and they vary meaningfully with plant types [54,55].

Pb accretion in rice noticeably concentrated leaf chlorophyll, protein and nitrogen matters, carotenes, and hill reaction while higher several enzymatic undertakings like catalase, ribonuclease, and acid phosphatase [56]. There has been an important alteration of lead uptake, and translocation was noticed in diverse rice cultivars and originate a declining tendency of lead contented from roots to rice grains. [57]. decreases in rice development and yield at 1200 mg of lead kg−1 of soil than control and originate lower Pb2+ contents in rice grains than root, shoot, and leaves [58]. Approximately 1216, 179, and 62 times higher lead substances remained detailed in roots, stems, and leaves, respectively, than grains at maturity [57]. Pb2+ ions current in the soil clarification when adsorbed to the root superficial [59]. The effect of Pb toxicity on photosynthetic machinery varies with rice genotype. Normally, chlorophyll b is more prone to distortion under Pb-stressed conditions than chlorophyll a [60].
3.3. Iron.

Iron toxicity occurs when the rice plant accumulates a toxic concentration of Fe in the leaves. The occurrence of Fe toxicity is associated with a high concentration of Fe(II) in soil solution [61]. It specifically affects rice production because the low soil redox potential of flooded rice paddies leads to the prevalence of the reduced and soluble Fe²⁺ (ferrous), as opposed to well-aerated soils, in which sparingly soluble forms of oxidized Fe³⁺ (ferric) are dominant. Fe toxicity can occur in variable soil types, including acid sulfate or acid clay soils with inherently high Fe concentrations, or poorly exhausted sandy soils in valleys receiving Fe rich runoff water from adjacent slopes. Fe toxicity causes substantial yield losses in rice and can lead to complete crop failure in severe cases [62]. Rice yield losses because of Fe toxicity were reported to range from 12% to 100%, depending on the cultivated varieties and the stress intensities [63]. The occurrence of Fe poisonousness in low-lying rice can be prejudiced by decrease goods such as sulfides and organic acids. The dangerous concentration of Fe(II) for the growth of Fe toxicity indications differs from as low as 10 to as high as 500 mg L⁻¹, liable mainly on the nutrient position of the plant and the occurrence of reduction goods. In the lack of damaging levels of decrease crops and a suitable source of plant nutrients, the rice plant agonizes from Fe toxicity at Fe (II) attentions higher than 300–500 mg L⁻¹. [64, 65]. The upbringing of open-minded rice diversities establishes an influential method to report the problem of Fe toxicity. In source, two physiological approaches may be beleaguered in attaining this aim: (i) Prohibiting of Fe at the root surface by oxidation of Fe²⁺ into inexplicable Fe³⁺, which principals to the development of a root plaque, i.e., causes of Fe at the root surface. Root architectural traits favoring this process include the formation of aerenchyma and a great amount of fine lateral roots, which enable the diffusion of oxygen into the rhizosphere, thereby increasing the redox potential above the threshold for Fe oxidation [62, 66].

3.4. Cadmium.

Cadmium (Cd) is solitary of the chief contaminants in paddy fields, and its gathering in rice (Oryza sativa L.) and succeeding transference to the food chain is a global ecological problem [67]. It was stated that Cd could be willingly occupied up by rice and translocated to shoot and formerly to grains [68, 69]. Therefore, Cd can arrive into the food chain over rice intake, uniform at low Cd concentrations in the soils, and source harmfulness to people [70, 71]. Cadmium poisonousness limited rice growth as projected in relation to root and shoot length, leaf and root extent, and amount of leaves and origins per vegetable [69, 72]. Overall, rice takes up Cd in the form of Cd²⁺ from the soils. Cadmium acceptance in rice plants diverges with soil pH, and biological substance gratified current in the soils [73]. Cd is occupied up by plant roots and disturbs animals, and humans concluded the food chain [74]. Cd toxicity is recommended to straight and/or ultimately prevent physical procedures and morphological growth in higher plants. In addition, Cd decreases plant chlorophyll fillings and prevents leaf photosynthesis [75].

3.5. Mercury.

Mercury (Hg) is a worldwide and tremendously poisonous contaminant [76]. Important Methyl mercury accretion in rice has presently haggard enlarged worldwide consideration. Early information is typically absorbed on the purpose of Hg altitudes in rice and the valuation of human contact risk through rice consumption [77]. Furthermore, of collected Hg in florae
leftovers in roots and only a small amount can be translocated to shoots [78]. The atmospheric Hg, which endures oxidation responses and deposits to the ground, upsurges the plenty of Hg in soils and waters [79]. Moreover, significant quantities of mercury presented into agricultural soils in the procedures of mercury-containing mixtures such as manures, pesticides, lime, and soil alterations underwrite a great arrangement to mercury contamination [80].

3.5. Zinc.

Zinc (Zn) absence is a nutrient illness that decreases rice (Oryza sativa L.) crops on millions of hectares universal [81,82]. These studies recommended that zinc absence in flooded rice was predominantly related to alkaline calcareous soils having organic substance fillings in extra of around one percent and that the occurrence of the illness was extreme in the two to six week period after soil submergence [83]. In rice (Oryza sativa) sprout meristems, more than 10 times the quantity of zinc was establish related to developed leaf blades. Though, the molecular mechanisms fundamental preferential transfer of zinc to these emerging issues are unidentified [84]. The obligation of Zn in steadying of plant cell membranes is owing to its ability to regulate the level of oxidizing \( \text{O}_2 \) species by an NADPH oxidase [85].

3.6. Nickel.

Nickel (Ni) is a crucial component for plant development [86]. Current studies have exposed that Ni is obligatory in small quantities for normal plant growth and development, and its shortage is infrequently stated, while its noxiousness is a substance of worry [87]. Nickel (Ni) is one of the lethal metals, which harmfully disturb plant development by changing diverse physical and metabolic methods [88]. Owing to the upsurge in anthropogenic activities, soil contamination by heavy metals comprising Ni\(^{2+}\) has gradually increased [89]. Nickel persuaded important reserve of evolution in plants and particularly in roots of bean plants after 4 days contact, which approves preceding consequences [90].

3.7. Copper.

Amongst the heavy metals, copper (Cu) is measured vital in trace quantities and controls numerous physical and chemical methods involve in shrub evolution, growth, and protecting contrivances. Soil hardly harvests extreme stages of Cu on its personal. Though, anthropogenic actions such as recurrent usage of Cu-comprising fungicides and slurries raise Cu to poisonous levels in soils. Once Cu pollution happens, it can persevere for numerous ages as of its small solubility and agility [91, 92]. Paddy rice is solitary of the most significant yields in the ecosphere. Rare studies have been directed on the alterations in the gathering of copper in brown rice and the consequence of copper on rice evolution and grain crop amongst cultivars. The current research was accompanied with 38 rice cultivars rising in the regulator and Cu-treatment paddy soil, to (1) examine the result of Cu on rice progress, grain crop, and Cu concentration in brown rice amongst diverse rice cultivars; (2) assess whether a healthiness danger is modeled by the entrance of the Cu in brown rice into the food chain; and (3) confirm the theory that showing for cultivars with low Cu gathering in brown rice and high grain yield is feasible, and it would be a good method to find suitable rice cultivars for Cu-contaminated areas [93]. Paddy rice has one of the greatest significant yields worldwide, and particularly in Asia. Raised Cu altitudes might prevent the progress and expansion of rice plants, and the growth of Cu in rice grain is straight connected to rice protection. Then the relative amid soil
Cu level and its poisonousness to rice development and the capability of rice grain to gather Cu in Cu-polluted soil is distant from rich. So this scheme was meant to examine the influence of soil Cu levels on rice growth and the relationship among grain Cu approval and soil Cu stages [9].

4. Adverse effects on human health by rice

Owing to cumulative industrialized growth, the pollution of paddy rice by carcinogenic and poisonous contaminants such as heavy metals has amplified, with the latent to consume an opposing influence on the whole diet series and afterward on human condition [94]. Food pollution by heavy metals has developed a severe problematic in current ages since of their latent gathering in Biosystems concluded polluted water and soil causes [95]. Alive organisms need variable quantities of vital heavy metals. Iron, cobalt, copper, manganese, molybdenum, and zinc are essential for chemical methods. Extreme levels can be damaging to the human condition. Further, heavy metals such as mercury, cadmium, chromium, and lead are poisonous metals, and their gathering concluded the period in the alive organisms could cause severe effects [96].

4.1. Obesity.

Obesity is known as an illness of irregular or extreme fat gathering in adipose tissue, to the amount that fitness may be reduced [96, 97].

4.2. Cardiovascular disease.

Cardiovascular illnesses (CVD), account for 30% of deceases, and resultant in 17.5 million deceases annually, is the most important reason for illness and death [98]. In current ages, attention has been rising towards alternate treatments for CVD as of enlarged problem of CVD despite developments in conservative beneficial apparatuses and tools. The salutation of nutrition as a significant adjustable in the action of CVD has meaningfully pretentious current methods to CVD organization [99]. The etiology of CVD comprises atherosclerosis, an inflammatory process that leads to hardening and narrowing of blood vessels, plaque build-up in vessel walls, and ultimately plaque break, heart attack, or stroke. Adaptable danger issues that show a character in the growth of atherosclerosis comprise corporeal inactivity, overweight, and obesity [7].

5. Discussion

This review study explained that the concentration level of heavy metal in rice is increasing all over the world. The heavy metal present in the rice causes unknown toxicity to the human body, but they are not toxic. Rice absorbs the very toxic heavy metals from the soils and water that are much effective for the plants. People who are allergic to rice may be affected by acute symptoms, like sneezing, itching, gastrointestinal problems, running nose, Asthma, Anaphylaxis, in rare cases. Due to the excessive intake of rice, the person may go to coma or death, which may also occur in very rare cases. It shows the carcinogenic effects in humans, and brown rice increases the risk of heart disease and type of cancer.
6. Conclusions

In conclusion, rice is the main grain crop in India. India ranks second in the world in the production of rice. Analytical techniques that are used to detect the concentration level of heavy metals in the rice from the body are HPLC, spectrophotometer, GC-MS, LC-MS, XRF-ED, paddy-check, etc. The texture analyzer is also an instrumental technique that detects the stickiness, hardness, cohesiveness, etc. Moreover, a great deal of attention should also be paid regarding the contamination of heavy metal in the rice through the food chain. Relevant data are still limited, and further studies need to be conducted.

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Conflicts of Interest

The authors declare no conflict of interest.

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