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ASSESSMENT OF HEAVY METAL CONTAMINATION IN PLASTIC MUGS, FREQUENTLY USED AT LOCAL RESTAURANTS OF DIFFERENT DISTRICTS OF U.P. INDIA

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ABSTRACT

A total number of 42 mugs manufactured from plastics (locally made) were purchased and analyzed to determine the level of zinc, nickel, iron and cadmium. All samples were digested with concentrated nitric acid (HNO_3),(USP-400220 method) and analyzed by using atomic absorption spectrophotometer (AAS) to determine heavy metal concentration. The results obtained showed the highest mean concentrations of (Zn: 0.864ppm in double distilled water, Ni: 0.691ppm in 8% ethanol, Fe: 0.654ppm in double distilled water and Cd: 0.01ppm in double distilled water) and also revealed that the leaching of these metals was temperature dependent *i.e* high at higher temperatures. The sample analyzed showed the following pattern: Zn>Ni>Fe>Cd.

Keywords: Plastics, Heavy metals, Leachates, Additives.

INTRODUCTION

Plastics have many unique properties in terms of their manufacturability and production possibilities, and these are being increasingly utilized in all fields of life. Plastics contain a wide variety of additives like plasticizers, antioxidants, stabilizers, curing agents, colouring agents etc. to fulfill their physical and chemical properties. These additives are present in a wide range of concentrations usually form trace (µg/Kg) to a few percent level. The finished plastics are generally considered to be safe if they are manufactured at standard conditions using permitted chemicals recommended by national and international regulatory agencies and used properly [1-9]. Many inorganic chemical additives can be added to plastics in order to get desired physical, chemical, or mechanical properties. Additives used as stabilizers may include calcium and zinc. Pigments often contain metals such as lead, tin, arsenic, nickel, cadmium, barium, aluminum, titanium, and iron. These additives are not chemically bound to the matrix of the polymeric materials and leach out under the influence of physicochemical factors such as sun light, temperature, and type of solvents and also the pH of the stored commodity, [10-17] and going to release hazardous substances from plastic products to air, extraction fluids, water, food, food simulants, saliva and sweat etc. Zinc based organic compounds are often used to initiate polymerization and wide ranging trace levels of zinc are found in plastic diluents [18]. There are numerous reports on the leachable, such as metals, DEHP, cyclohexanone and other organic and acidic compounds found in the solution of plastic articles [19-23]. Heavy metals, such as Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn are leached out in the simulating solvents from the finished plastic products [14, 24]. This can affect the normal physiological activities of the cells and other organs, as the levels of these metals were found above the permissible limits.

Lead poisoning from plastics causes learning disabilities, kidney failure, anaemia and irreversible brain damage in children [25]. Children and pregnant women are particularly susceptible to lead poisoning [26-28].The digestive system of children absorbs up to 50% of the lead they ingest. In fact, physicians and scientists agree that

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no level of lead in blood is safe or normal [29]. Cadmium compounds are used as stabilizers in PVC products, colours & pigments. Cadmium exposure produces a wide variety of acute and chronic effects in humans, leading to abuild-up of cadmium in the kidney that can cause kidney disease [30]. The IARC has classified cadmium as human carcinogen (group-1) on the basis of sufficient evidence in both humans and experimental animals [31]. Lead and cadmium are known poisons, being neurotoxins and nephrotoxins [32]. European studies have shown signs of cadmium induced kidney damage in the general population at urinary cadmium levels around 2-3 μgCd/g creatinine [33,34].

Nickel in small amount is needed by the human body to produce red blood cells; however, in excessive amount, can become mildly toxic. Short-term over exposure to nickel is not known to cause any health problems, but long-term exposure can cause loss of body weight, heart and liver damage, and skin irritation. Although zinc is an essential requirement for good health, excess zinc can be harmful. Excessive absorption of zinc suppresses copper and iron absorption [35] .The free zinc ion is a powerful Lewis acid up to the point of being corrosive. Stomach acid contains hydrochloric acid, in which metallic zinc dissolves readily to give corrosive zinc chloride. This chloride can cause damage to the stomach lining due to the high solubility of the zinc ion in the acidic stomach [36]. The U.S. Food and Drug Administration (FDA) has stated that zinc damages nerve receptors in the nose, which can cause anosmia [37]. Chromium metal and chromium (III) compounds are not usually considered health hazards; chromium is an essential trace mineral. Hexavalent chromium is very toxic and mutagenic when inhaled, as publicized by the film 'Erin- Brockovich', which was released in March, 2000.

Cobalt is an element that can be both beneficial to an individual's health and detrimental to it. At its lowest levels, cobalt can be found in the chemical makeup of vitamin B-12, which is necessary for optimum health, but if the body comes in contact with a high level of cobalt, it could ultimately be harmful to the heart and lungs [38].

Manganese over exposure is most frequently associated with manganism. Manganism is a biphasic disorder. In its early stages, an intoxicated person may experience depression, mood swings, compulsive behaviors, and psychosis. Early neurological symptoms give way to late-stage manganism, which resembles Parkinson's disease. Symptoms include weakness, monotone and slowed speech, an expressionless face, tremor, forward-leaning gait, inability to walk backwards without falling, rigidity, and general problems with dexterity, gait and balance [39].

Physicians and scientists agree that no level of heavy metals in blood is safe or normal. The disturbing fact is that exposure to extremely small amount can have long-term and measurable effects in children while at the same time showing no distinctive symptoms. Another problem of heavy metals exposure is it being cumulative in nature. After they have been absorbed into the blood, some of them are filtered out and excreted, but the rest are distributed in the liver, brain, kidney and bones [40].

This study determined the current pattern in the use of heavy metals as stabilizer in plastic mugs, using analytical techniques that would yield empirical data. The data collected were used to provide a clear picture of hazardous chemicals in plastic mugs.

MATERIALS AND METHODS

A total of 42 samples of plastic mugs used in the present study were purchased from local markets of Lucknow, Allahabad, Mau, Varanasi and Kanpur districts of Uttar Pradesh India for the assessment of heavy metals (Zn, Ni, Fe and Cd) and categorized into 6 groups on the basis of their colour (blue, green, Purple & white 5 brands each; yellow, maroon, red & grey 4 brands each; pink, light blue & sky blue 2 brands each), because metal contamination greatly depend on the colouring materials which are used in manufacturing of plastics [41].

All samples were washed thoroughly with sterilized double distilled water prior to the leaching. Double distilled water, Ethanol (8% v/v) and Sodium Chloride (0.9% w/v) were used as the simulating solvents and then the samples of mugs were exposed in 100 ml of each simulating solvents in sterile beakers at a ratio of $2cm^2$ /ml. The samples were kept at 60 ± 2^0C for 2 hrs (elevated condition), 25 ± 2^0C for 24 hrs (ambient condition) and 4 ± 1^0C for 72 hrs (refrigerated condition). Parallel sets having simulating solvents only were also run under identical conditions and it was serving as basal control [42]. The simulated solvents 100 ml were taken in conical flask and digested with concentrated nitric acid in a fuming chamber. The digested samples were scaled down to 10 ml with 0.1 N HNO_3.The final processed samples were quantitatively analyzed by using Perkin- Elmer-500 atomic absorption spectrophotometer (USP-400220). The instrument was first calibrated with standards prepared from stock solution provided by Merck. The concentrations of the selected heavy metals were determined in triplicate and the result is given as a mean ± standard deviation. The concentrations of metals in different leachates of samples are presented in ppm. Metal content should not be more than 1.000 ppm (Cd should not be more than 0.100 ppm) according to BIS, IP, USP and other regulatory agencies.

Statistical analysis

The results were expressed as mean ± standard deviation and comparisons were made by applying one way analysis of variance (ANOVA) to assess the level of significance using computer based software 'Graph Pad PRISM-5'. The *p* valueless than 0.05 marked with * in fig.1-20, is considered as significant.

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RESULTS AND DISCUSSION

The findings indicate that the leaching of heavy metals in mugs were temperature as well as solvents dependent. The leaching of various heavy metals was as follows.

Estimation of Zn

In leachates of double distilled water, the mean concentration of zinc varied between the range of 0.864ppm (in white samples at elevated condition) and 0.007ppm (in maroon samples at refrigerated condition) (fig.1). In case of 3% acetic acid, the maximum mean concentration of zinc was noted in grey samples (0.541ppm) at elevated condition, while minimum in maroon samples (0.002ppm) at refrigerated condition. (fig.2). In 8% ethanol at elevated condition, the maximum migration of zinc was observed in yellow coloured samples (0.777ppm), while in samples of light green coloured the leaching of zinc was minimum (0.009ppm). (fig.3)

The leaching of Zn in 0.9% sodium chloride was ranging between 0.814ppm (in yellow samples elevated condition) and 0.006ppm (in pink samples at refrigerated condition). (fig.4). In 5% sodium carbonate, the maximum migration of zinc heavy metal was observed in yellow coloured samples (0.654ppm) at 60±2^{o} C for 2 hrs condition, whereas it was not detected in white and pink samples at refrigerated condition. (fig.5)

Estimation of Ni

The maximum leaching of Ni was detected in purple coloured samples (0.419ppm) in leachates of double distilled water at elevated temperature, whereas it was not detected in green, yellow, light green and pink coloured samples nearly at all treated conditions. (fig.6)

In 3% acetic acid, the maximum leaching of Ni was obtained in red samples (0.351ppm) at elevated condition, while minimum in white samples (0.002ppm) at refrigerated condition (fig.7).

At 60±2^{o} C for 2 hrs condition, the maximum mean concentration was detected in pink coloured samples (0.691ppm) in the leachates of 8 % ethanol, on the other hand it was not detected in white, yellow and light green coloured samples at 4±1^{o} C condition (fig.8).

In leachates of 0.9% sodium chloride, the maximum mean concentration of nickel was noted in pink coloured samples (0.470ppm) at elevated condition, while not detected at refrigerated condition in grey coloured samples (fig.9).

The analysis for Ni in leachates of 5 % sodium carbonate showed that the presence of this metal was ranging between 0.333ppm (in blue samples elevated condition) and 0.008ppm (in green samples at refrigerated condition) (fig.10).

Estimation of Fe

The highest mean concentration of iron in double distilled water was found in yellow coloured samples (0.654ppm) at elevated condition, while it was not detected in maroon samples at refrigerated condition and in light green samples under all conditions of temperature (fig.11).

The highest mean concentration of Fe in 3% acetic acid was observed in purple coloured samples at elevated condition (0.47ppm), while it was not detected in any of the samples at refrigerated condition and also in some samples at ambient condition (fig.12).

In 8% ethanol, the maximum leaching of Fe was obtained in red coloured samples (0.415ppm) at elevated condition, whereas it was not detected in grey and sky blue coloured samples at refrigerated condition (fig.13).

In leachates of 0.9% sodium chloride, the maximum mean concentration of iron was from sky blue coloured samples (0.329ppm) at elevated condition, while in majority of samples, it was not detected at all treated conditions of temperature (fig.14).

In 5% sodium carbonate, the maximum migration of iron heavy metal was observed in grey coloured samples (0.555ppm) at 60±2^{o} C for 2 hrs condition, whereas in majority of samples it was not detected at all treated conditions of temperature. (fig.15)

The analysis was also performed for detection of Cd and the results revealed that only at elevated conditions some leaching has been observed within the prescribed permissible limit, the highest mean concentration was observed only in yellow samples in all solvents (fig.16-20).

Figure 1. Concentration of Zn in leachates of mugs in double distilled water. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

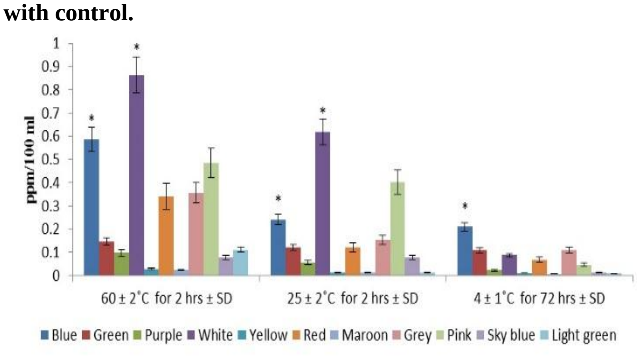

Figure 2. Concentration of Zn in leachates of mugs in 3% acetic acid. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

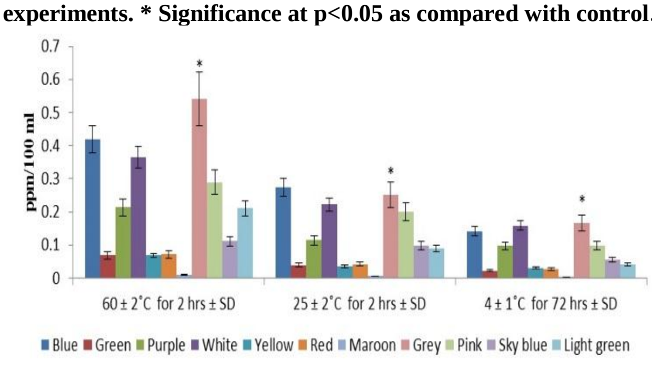

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Figure 3. Concentration of Zn in leachates of mugs in 8% ethanol. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

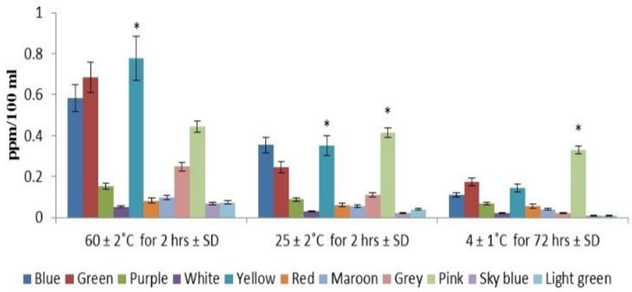

Figure 4. Concentration of Zn in leachates of mugs in 0.9% sodium chloride. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

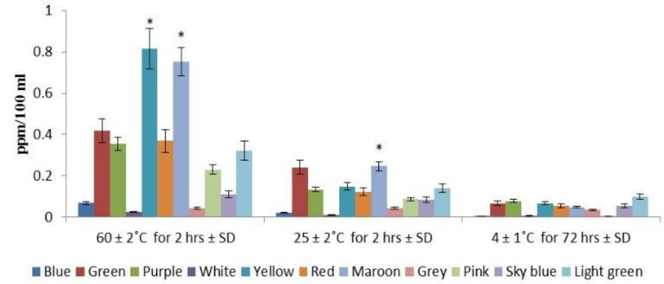

Figure 5. Concentration of Zn in leachates of mugs in 5% sodium carbonate. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

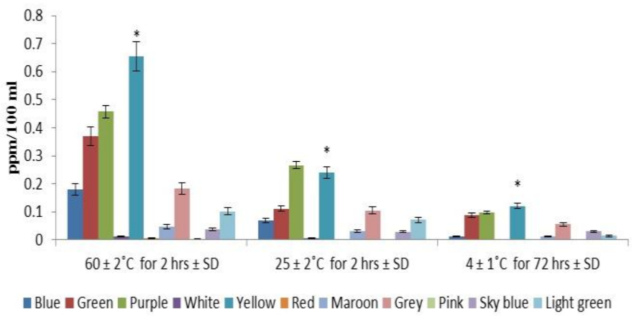

Figure 6. Concentration of Ni in leachates of mugs in double distilled water. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

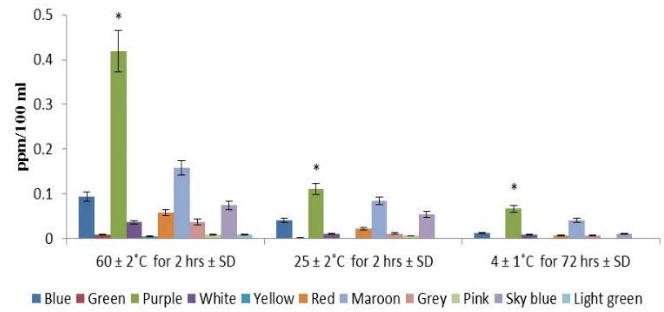

Figure 7. Concentration of Ni in leachates of mugs in 3% acetic acid. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

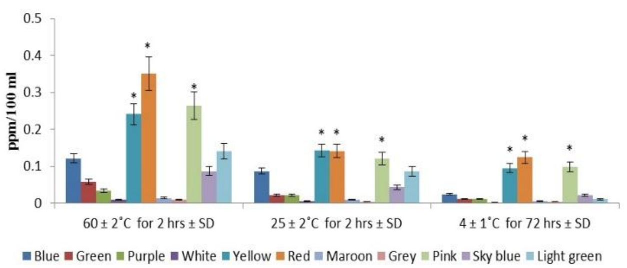

Figure 8. Concentration of Ni in leachates of mugs in 8% ethanol. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

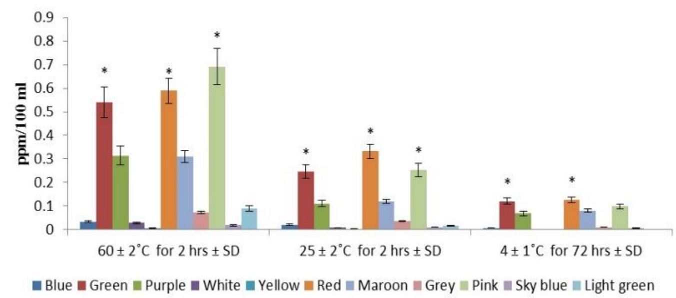

Figure 9. Concentration of Ni in leachates of mugs in 0.9% sodium chloride. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

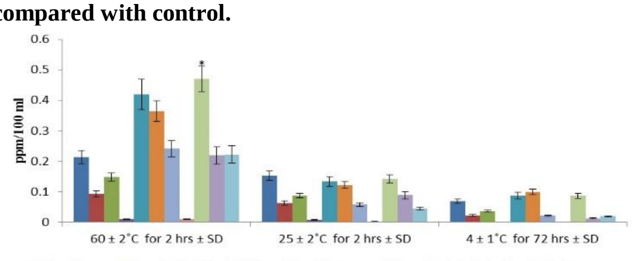

Figure 10. Concentration of Ni in leachates of mugs in 5% sodium carbonate. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

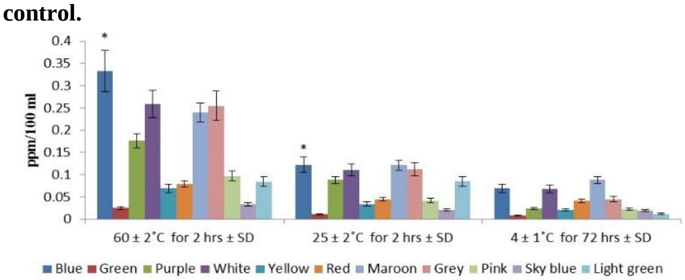

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Figure 11. Concentration of Fe in leachates of mugs in double distilled water. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

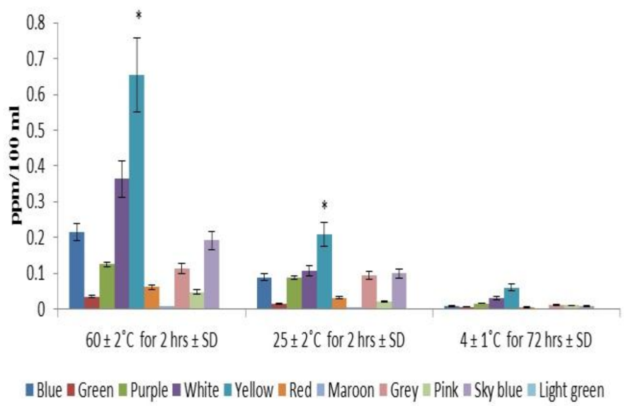

Figure 12. Concentration of Fe in leachates of mugs in 3% acetic acid. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

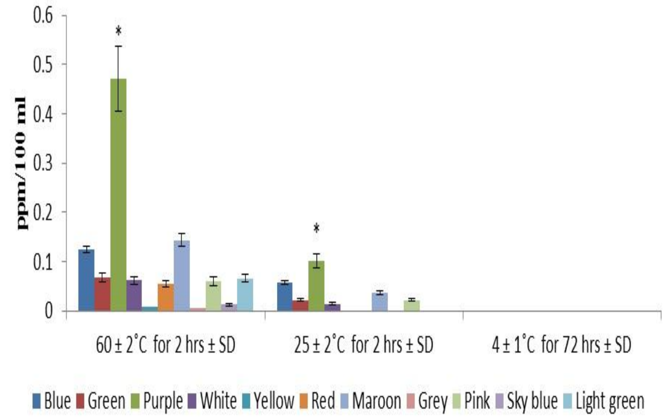

Figure 13. Concentration of Fe in leachates of mugs in 8% ethanol. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

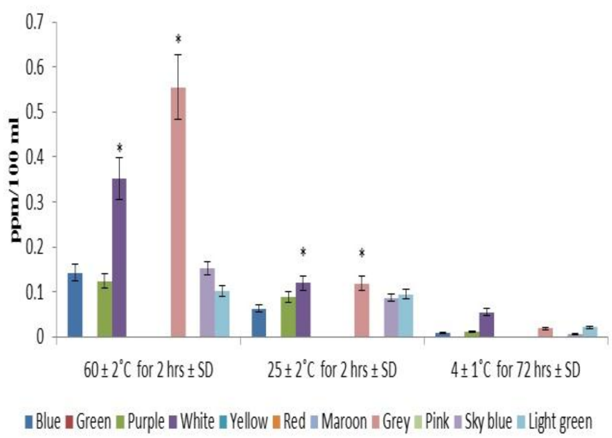

Figure 14. Concentration of Fe in leachates of mugs in 0.9% sodium chloride. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

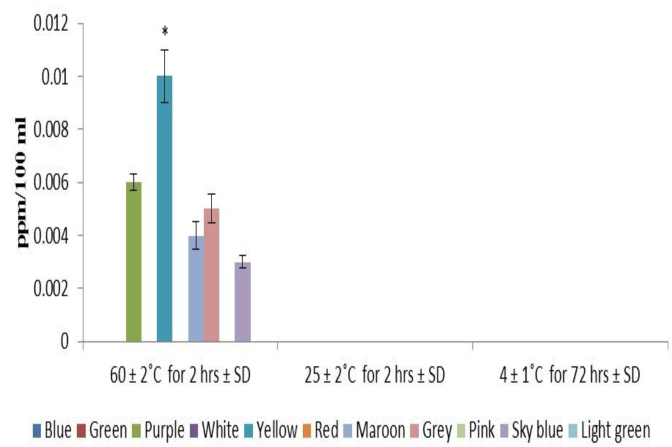

Figure 15. Concentration of Fe in leachates of mugs in 5% sodium carbonate. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

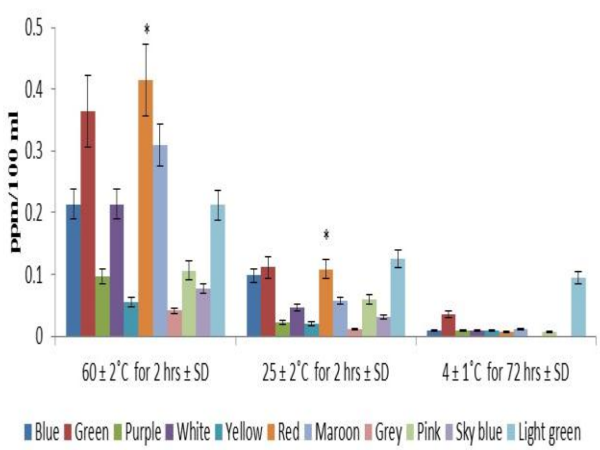

Figure 16. Concentration of Cd in leachates of mugs in double distilled water. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

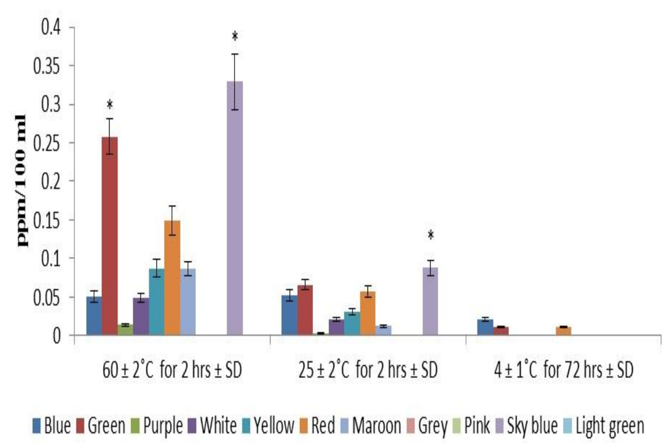

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Figure 17. Concentration of Cd in leachates of mugs in 3% acetic acid. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

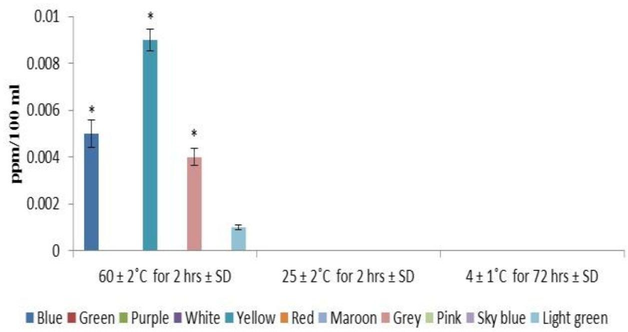


Figure 18. Concentration of Cd in leachates of mugs in 8% ethanol. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

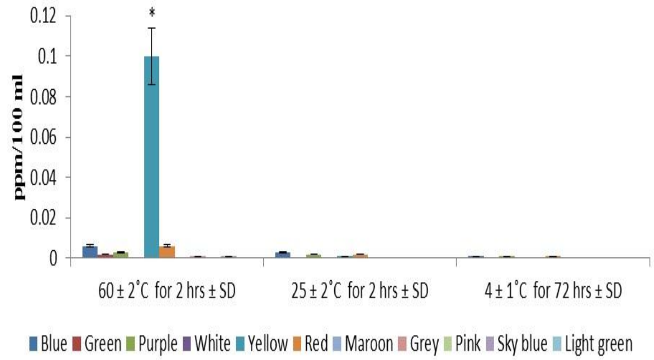


Figure 19. Concentration of Cd in leachates of mugs in 0.9% sodium chloride. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.

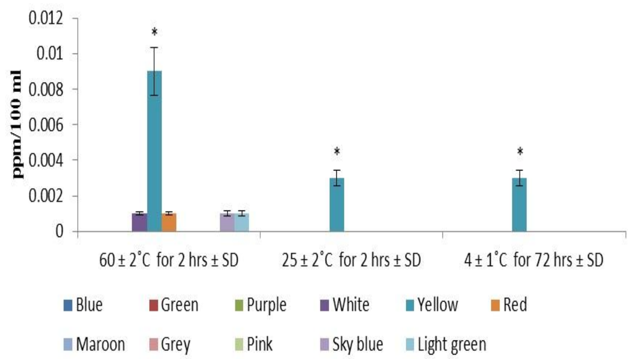
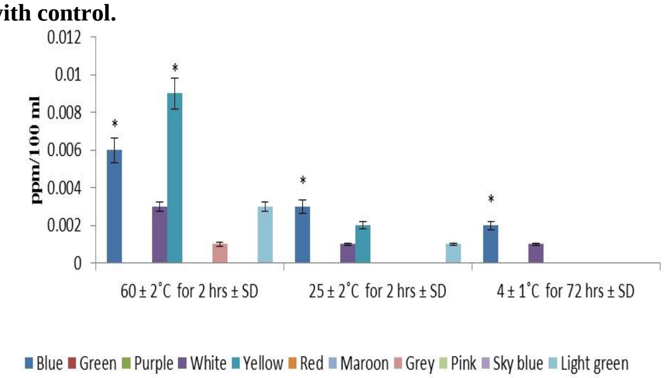


Figure 20. Concentration of Cd in leachates of mugs in 5% sodium carbonate. The results were reported as a mean ± SD from three set of experiments. * Significance at p<0.05 as compared with control.



CONCLUSION

The mugs purchased from various districts of U.P. India contain toxic heavy metals in varying concentrations and most of them showing high concentrations that may pose hazards to human's as well as animal's health and create a major health hazard in its use and disposal especially at high temperatures.

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