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Quantitative analysis of cadmium, chromium and nickel in different water resources of Jabalpur by ICP-OES

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Abstract
Heavy metal pollution is a serious problem for the environment due to their toxicity, bioaccumulation and bio magnification property. It can occur from different natural and anthropogenic sources. The mobilization of these heavy metals to the aquatic ecosystem alters the physicochemical property of water which is hazardous for aquatic water ecosystem. They mainly enter the fish body through gills, body surface and digestive tract during ingestion of metal accumulated food materials. Cadmium, chromium, nickel, arsenic, copper, mercury, lead and zinc are the most common heavy metal pollutants that cause severe toxicity in fishes. In this study, a total of 252 samples from various water sources were collected and screened. The study revealed that presence of cadmium-69.80%, chromium-72.60% and nickel-78.17%. The concentrations were found between 0-0.066 ppm, 0.004-0.269 and 0.006-0.192 ppm of Cd, Cr and Ni respectively. The findings indicates poor sanitary practices and effluents contamination in water resources and thus, there is a need of immediate preventive and corrective measures to preserve the wholesome quality of water.

Keywords: Heavy metals, toxicity, inductively coupled plasma, optical emission spectroscopy

1. Introduction

Water "the mother and matrix of life" is facing a severe threat due to pollution. Rapid industrialization and indiscriminate use of chemicals, fertilizers and pesticides in agriculture are causing heavy and varied pollution in the aquatic environment leading to deterioration of water quality and depletion of aquatic biota [1]. Among them, heavy metals are playing a major role in environmental pollution, not only for their toxic nature but also possessing the potentiality of bioaccumulation in the food chain. Since heavy metals are persistent in the natural ecosystem, once enter into the living organism, it can accumulate inside. The heavy metals can easily dissolved in the aquatic environment and subsequently enter into the body of aquatic organisms. In the course of the food chain, those metals then enter into the body of higher animals. Bioaccumulation of toxic heavy metals in the different tissues may harm animal health and causes damage to their normal physiological processes [2]. Heavy metal toxicity drastically affects the rate of survivability and reproductive capacity of the organisms. Some of these have been reported to be highly carcinogenic, mutagenic and teratogenic depending on the species, dose and exposure time. Aquatic biota directly exposed to the heavy metals that dissolved in water or present as sediment in the water body. Being the top consumers of the aquatic ecosystem fishes are affected most. Heavy metal toxicity sometimes damages the nervous system of fish that affects the interaction of fish with its environment. Humans are omnivorous and exposed to toxic heavy metals by different aquatic food items. Therefore, the heavy metal contamination in the body of aquatic organisms or plants can biomagnified and persist in the food chain, results in transfer to the human body. Heavy metal toxicity has become an important global threat for fish consumers [3]. Heavy metals can directly influence behaviour by impairing mental and neurological functions, influencing neurotransmitter production and utilization and alternating numerous metabolic body processes. Systems in which toxic metal elements can impair and dysfunction include the blood and cardiovascular eliminative pathways (colon, liver, kidneys and skin), endocrine (hormonal), energy production pathways, enzymatic and immune systems [4].

2. Materials and Methods

2.1 Sample Collection

Approximately 200 ml of water samples were collected in polypropylene bottles from ponds, different banks of river Narmada, hand pumps, tube wells and public taps of Jabalpur city for analysis of heavy metals like Cadmium, Chromium and Nickel. Collected samples were stored in refrigerator at 4 ºC till further analysis. The details of sample collection are described in table 1.

Table 1: Samples from different water sources

S. No.	Sources of water samples	Total number
1.	Different banks of river Narmada	30
2.	Ponds	60
3.	Hand pumps	60
4.	Public taps	60
5.	Tube wells	42
Total		252

2.2 Processing of water samples

Water samples were acid digested, briefly 1.5 ml of sample taken into a conical flask and mixed with 6 ml of con. nitric acid and 2 ml of 30% hydrogen peroxide. The mixture was transferred to microwave digestion tubes and digested in Microwave digester (ETHOS UP) for 45 minutes. The digested samples was rinsed with Mili Q water and the volume made upto 10 ml and stored at 4 °C till further metal analysis [5].

2.3 Estimation of heavy metals by inductively coupled plasma optical emission spectroscopy (ICP-OES)

Inductively coupled plasma optical emission spectroscopy (ICP-OES) (Thermo scientific, iCAP 7000 series) was used for the estimation of heavy metals in the samples. Argon flame was used as a fuel. Processed samples were thawed to room temperature. Calibration of instrument was achieved with 5 standards of known concentrations (10, 50, 100, 200 and 400 ppb) prior to analysis of unknown sample. Sample was analysed by making work list in attached computer. Concentrations of heavy metal in the samples were obtained in ppb which further converted to ppm for data presentation.

Table 2: Operating condition of inductively coupled plasma optical emission spectroscopy (ICP-OES)

Element	Cadmium	Chromium	Nickel
Product type	iCAP 7400 ICP-OES DUO	iCAP 7400 ICP-OES DUO	iCAP 7400 ICP-OES DUO
Gas	Argon	Argon	Argon
Outer argon flow (L/min.)	15.00	15.00	15.00
Wavelength (nm)	226.502	283.563	221.647
Acquisition parameter	Microelement, axial view	Microelement, axial view	Microelement, axial view
Sample uptake time	45 sec	45 sec	45 sec
Standards (ppb)	10, 50, 100, 200, 400	10, 50, 100, 200, 400	10, 50, 100, 200, 400

2.4 Statistical analysis

The statistical analysis was done with IBM-SPSS-24 software with one way ANOVA and DMRT (Duncan's multiple range test).

3. Results and Discussion

The presence of heavy metals in the environmental samples (water, soil etc.) poses threat to the living world as their exposure as environmental pollutant may cause toxic effect on aquatic flora and fauna as well as humans. Anthropogenic activities such as mining, smelting operation and agriculture have increased the levels of heavy metals such as cadmium, chromium etc. Their toxicity are because these are persistent, bio accumulative, do not readily breakdown in the environment and are not easily metabolized. These metals accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels. Health risks of heavy metals are reduced growth and development, cancer, organ damage, nervous system damage and in extreme cases, death. The maximum permissible limit (MPL) of cadmium is 0.003 mg/L, chromium is 0.05 mg/L and nickel is 0.02 mg/L as per WHO [6]. These elements do not have any relaxation. The study revealed 69.80%, 72.60% and 78.17% samples had higher concentration than MPL for Cd, Cr and Ni respectively. The overall concentrations of cadmium, chromium and nickel were ranging from 0-0.066 ppm, 0.004-0.269 ppm and 0.006-0.192 ppm respectively as shown in table 3.

Table 3: Concentrations of heavy metals in different water sources

S. No.	Source	Cadmium	Chromium	Nickel
1	River Narmada	0-0.066	0.01-0.269	0.006-0.192
2	Ponds	0.001-0.009	0.008-0.092	0.008-0.094
3	Hand pumps	0.001-0.009	0.004-0.097	0.01-0.096
4	Public taps	0.001-0.009	0.015-0.098	0.01- 0.091
5	Tube wells	0.001-0.008	0.015-0.096	0.01-0.085
Overall		0-0.066	0.004-0.269	0.006-0.192

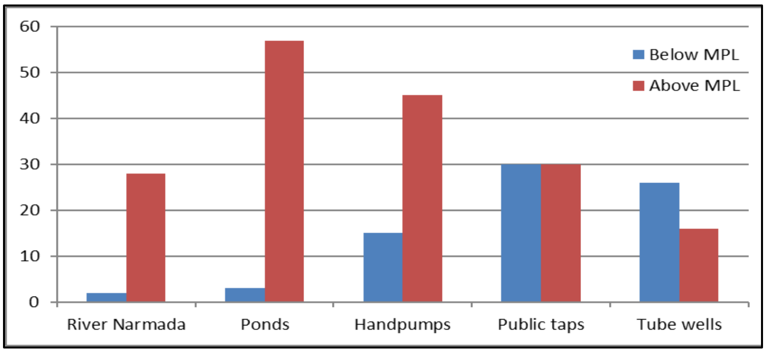

Fig 1: Water samples showing below and above maximum permissible limits of Cadmium

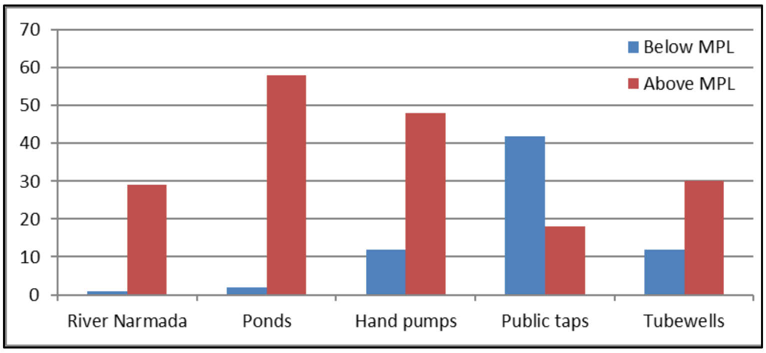

Fig 2: Water samples showing below and above maximum permissible limits of Chromium

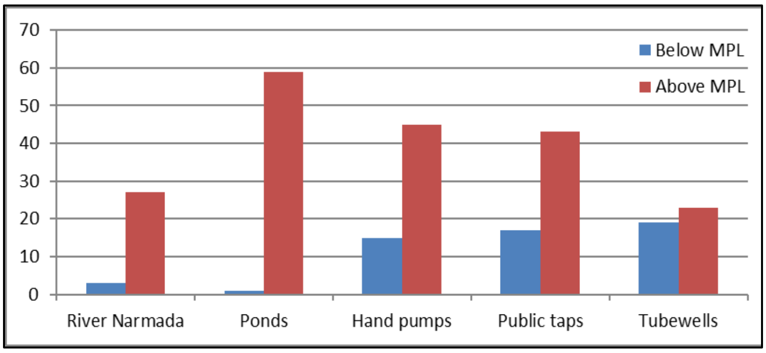

Fig 3: Water samples showing below and above maximum permissible limits of Nickel

In this study, the concentration of cadmium in water samples from river Narmada, ponds, hand pumps, public taps water and tubewells was found in range of 0-0.066 ppm, 0.001-0.009 ppm, 0.001-0.009 ppm, 0.001-0.009 ppm and 0.001-0.008 respectively. The concentration of chromium in water samples from river Narmada, ponds, hand pumps, public taps and tube wells and was found in range of 0.01-0.269 ppm, 0.008-0.092 ppm, 0.004-0.097 ppm, 0.015-0.098 ppm and 0.015-0.096 ppm, respectively and 0.006-0.192 ppm, 0.008-0.094 ppm, 0.01-0.096 ppm, 0.01-0.091 ppm and 0.01-0.085 ppm, respectively for nickel. Most of the samples analysed had cadmium, chromium and nickel concentration significantly higher than the maximum permissible limit as per recommended by WHO [6]. Out of 252 samples, 69.80%, 72.60%, 78.17% samples of cadmium, chromium and nickel had higher concentration than recommended MPL. Statistically, there was significant variation in cadmium, chromium and nickel. Source wise, it is revealed that the mean concentration of cadmium, chromium and nickel is significantly higher in river Narmada in comparison to ponds, hand pumps, public taps and tube wells whereas the mean concentration of nickel was higher in hand pumps, tube wells and public taps. Narmada water samples had significantly high concentration of chromium followed by cadmium and nickel as shown in table 4.

Table 4: Mean Concentration of heavy metals in different water sources (Mean±SE)

S. No.	Source	Cadmium	Chromium	Nickel
1.	River Narmada	0.011^{Ac}±0.002	0.114^{Aa}±0.013	0.058^{Ab}±0.008
2.	Ponds	0.003^{Bb}±0.0004	0.045^{Ba}±0.005	$0.037^{Ba\pm}$0.004
3.	Hand pumps	0.004^{Bb}±0.0004	0.0049^{Ba}±0.005	$0.051^{Aba\pm}$0.004
4.	Tube wells	0.004^{Bb}±0.005	$0.053^{Ba\pm}$0.005	$0.048^{Aba\pm}$0.004
5.	Public taps	0.005^{Bb}±0.02	$0.053^{Ba\pm}$0.004	$0.050^{Aba\pm}$0.004

Values with different superscript shows significant difference (p<0.05)

A similar study conducted by Ramchander and his coworkers showed the concentrations of cadmium and chromium was found moderately high as compared to WHO recommendation [7]. In another study by Kerketta and his coworkers revealed the mean values of cadmium was 0.04±0.01 to 0.11±0.03 which was more than the prescribed permissible limits of WHO [8].

Contamination with high levels of these heavy metals is of concern because they may cause a number of human health effects. These heavy metals may be neurotoxic, carcinogenic, mutagenic or teratogenic, can cause gastrointestinal (GI) disorders etc [9]. Rate of absorption and effect is also influenced by factors such as age and physiological status. The effects may be acute, chronic or sub-chronic depending upon the dose, duration and route of exposure.

Contamination of drinking-water with cadmium may occur as a result of impurity in the zinc of galvanized pipes or cadmium-containing solders in fittings, water heaters, water coolers and taps. The chronic exposure severely affects kidney. Cadmium affects the resorption function of the proximal tubules and glomeruli resulting in increase in the urinary excretion of low-molecular-weight proteins, known as tubular proteinuria. Disturbances in renal handling of phosphorus and calcium may cause resorption of minerals from bone, which can result in the development of kidney stones and osteomalacia [10].

Chromium presence in water may be due to its use in leather tanning industry, the manufacture of catalysts, pigments and paints, fungicides, the ceramic and glass industry, in photography, for chrome alloy and chromium metal production, chrome plating and corrosion control. Chronic toxicity is associated with allergic reaction. Adverse effects include ulceration, dermatitis and liver necrosis.

Nickel in water is leaching from metals in contact with drinking-water, such as pipes and fittings. However, nickel may also be present in some groundwater as a consequence of dissolution from nickel ore-bearing rocks. Allergic contact dermatitis (‘Nickel-itch’) and respiratory disorders is the most prevalent effect of nickel in the general population [11].

4. Conclusion

The presence of metals above the permissible limits in present study showed a threat/ hazard to people when consuming this water regularly. Overall accumulated heavy metals not only affect the fish population in the aquatic ecosystem but also transfer through the food chain/web to the next tropic level. Trophic transfer of these elements from aquatic to the terrestrial ecosystem has serious implications for human health by promoting different diseases including cancer, neurodegenerative disease etc. Therefore essential steps should be taken to minimize the toxic impact of heavy metals on human health, aquatic biota and the environment.

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