Qualitative Assessment of Heavy Metals and Radionuclides in Aquatic Systems

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1. INTRODUCTION

Uranium, a heavy metal, is a naturally occurring substance that exists in various chemical forms and plays a significant role in environmental radioactivity. It is found in abundance in sources such as granites, metamorphic rocks, lignite, carnotite, monazite sand, phosphate deposits, and uraninite. While uranium is not as common as other toxic elements like antimony, cadmium, bismuth, and mercury, it is present in higher amounts in the Earth's crust. Uranium can enter the environment through leaching from natural sources, nuclear industry emissions, nuclear weapons use, dissolution in fertilizers, and the burning of coal and other fuels.

The chemical and radioactive toxicity of uranium can have adverse effects on the kidneys and lungs. Chemical toxicity may be more important than radiological dose for uranium alone. Uranium's mobility is influenced by its chemical characteristics, and it can form complexes with soluble carbonates, allowing for significant mobility in neutral to basic soils. Uranium is also present in various minerals and is an important component of geochemical cycles.

Uranium mining for nuclear fuel, both for military and non-military purposes, can lead to environmental contamination and pose health hazards. Uranium mill tailings can contribute to radon emissions, soil and water contamination, and the pollution of groundwater and subsoil with radioactive and toxic metals. Uranium can also be found in seawater, well water, and municipal tap water, with concentrations varying depending on the source.

Heavy metal contamination, including uranium, is a global problem that can have severe health consequences. Biomagnification and accumulation of heavy metals in the food chain can lead to stunted growth, organ damage, cancer, and autoimmune disorders. Uranium can be released into the environment through the burning of coal in thermal power plants, resulting in the contamination of air, water, soil, and plants.

Uranium is naturally present in the Earth's crust, rocks, and soils, with concentrations varying depending on geological factors. The mobility of uranium in soil depends on several factors such as pH, redox potential, soil porosity, and particle size. The retention of uranium in soil can occur through adsorption, chemisorption, and ion exchange processes.

Chronic consumption of uranium through drinking water can have harmful effects on the kidneys and interfere with normal kidney function. Uranium is also present in coal, along with other radioactive substances, and can be released into the environment during coal combustion. Radiation exposure from natural and man-made sources, including nuclear reactions and thermal power plants, has always been a part of human life.

Monitoring uranium levels in groundwater, soil, and plants is crucial for assessing environmental contamination and potential health risks. Techniques such as ICP-MS can be used to determine uranium concentrations accurately. Proper measures should be taken to prevent uranium pollution in areas where mining and nuclear processing plants are present, including the installation of liners in ash ponds to prevent contamination of soil and groundwater.

Overall, understanding the presence and behavior of uranium in the environment is essential for assessing its environmental and health impacts and implementing appropriate measures to mitigate risks.

2.STATEMENT OF THE PROBLEM

Accurate measurement of radioactive concentrations and speciation in diverse environmental, biological, and geological materials is the main problem. Therefore, radio analysis technology is crucial to and essential to these efforts. Numerous separation and detection techniques have been created since radioactivity was first discovered more than a century ago and have been successfully used to identify different radionuclides. With the development of new separation and detection methods, significant advancements in conventional analytical methods, and a growing need for knowledge and information about radionuclide speciation, sensitive long-lived radionuclide detection using mass spectrometric methods like ICP-MS and accelerator mass spectrometry, as well as the development of numerous methods for quickly determining radionuclides of difficult to measure. In recent years, some laboratories have improved our current analytical methods for determining longlived radionuclides in the environment with a focus on improving the detection limit, automating analytical operation, quick determination and developed numerous analytical methods for speciation analysis of various radionuclides in environmental and biological samples. In this study, radionuclides (Uranium and Cesium) and heavy metals are analysed in various samples taken from the GDNP, Bathinda, and Talwandi Sabo Power Cooperation Limited (TSPCL), Mansa. Therefore, the objective of this research is to assess the level of natural radioactivity in soil and water samples and to determine the potential radiological health effects on the general population.

3.JUSTIFICATION OF THE STUDY

Keeping in view of above importance of problem, the present Study has been undertaken to assess the use of a quick and ultrasensitive isotope analytical method based on ICP-MS for determining the composition of uranium and Cesium isotopes, estimating the concentration of heavy metals in soil, water, and plants growing in various thermal plants, and assessing the impact of thermal pollution on plants growing inside and near thermal plants.

4.OBJECTIVES OF STUDY:

1. Estimate concentration of heavy metal and other radionuclides in different water samples i.e., hand pump, municipal water, water from inside and nearby thermal plant and estimation of Biological Oxygen demand in different water sample: Tap water, Hand pump water.
2. Estimate concentration of heavy metal and other radionuclides in soil samples collected from thermal plants.
3. To concentrate levels of heavy toxic elements such as Zn, Pb, Cu etc.
4. To determine the effective dose rates and absorbed dose rates in the ambient atmosphere.
5. To measurements of concentrations activity of radionuclides Such as H_2O

5.RESEARCH METHODOLOGY

The study focused on collecting water samples from two thermal plants in Punjab, specifically near and far from the plants where thermal pollution occurs. A total of 30 water samples were collected from each plant, including drinking water, hand pump water, cooling tower water, sewerage water, raw water, and canal water. The samples were collected in plastic bottles, filtered, and acidified to a pH of around 2 using nitric acid. The samples were labeled with details of the collection and transported to the laboratory for analysis.

The concentrations of natural uranium, cesium, and heavy metals in the groundwater samples were analyzed using inductively coupled plasma mass spectrometry (ICP-MS) at the Instrumentation Centre. The ICP-MS instrument used was a Perkin-Elmer Sciex ELAN DRC II. The analysis recorded the results in parts per million (ppm) and parts per billion (ppb) levels. To ensure the stability and comparability of the water samples, the sampling bottles were soaked in 10% nitric acid, rinsed with deionized water, and filtered before use. Each sample was acidified with nitric acid to prevent metal precipitation. The elemental analysis of the water samples was conducted using ICP-MS, and the liquid samples were typically aqueous, acidified, filtered, and had a total dissolved solids content of less than 1000 ppm.

Standard solutions for calibration were prepared using a multi-element standard solution, and four standard solutions were prepared at different concentrations (1000 ppb, 500 ppb, 100 ppb, and 10 ppb). These standard solutions, along with the water samples, were analyzed using ICP-MS.

ICP-MS is a technique that utilizes inductively coupled plasma and mass spectrometry to determine the concentration of elements in samples. It has a detection limit of 0.1 µg/liter and a between-run precision of less than 6%. The method used in this study utilized recent advances in collision/reaction cell technology to reduce molecular ion interference, resulting in improved accuracy and expanded scope of analysis. The ICP-MS analysis was performed to estimate the concentrations of uranium, cesium, and heavy metals in the water samples. The study collected water samples from thermal plant areas, prepared them for analysis, and used ICP-MS to determine the concentrations of uranium, cesium, and heavy metals. The method involved acidification, filtration, and calibration with standard solutions to ensure accurate results. ICP-MS was chosen as the analytical technique due to its detection limit and precision.

6. RESULT AND FINDINGS

Analysis of uranium, cesium and heavy metals (Cr, Cu, Mn, Pb, As, Zn, Ni, Cd and Hg) in different water samples collected from Guru Nanak Dev Thermal Plant, Bathinda and TSPCL is done by ICP-MS technique. Results of analysis are shown in table 3.2-3.5.

Uranium concentration is high in Guru Nanak Dev Thermal Plant, Bathinda as compared to Talwandi Sabo Power Cooperation Limited (Mansa).Uranium is found in the range of 1.10 ppb (drinking water sample from TSPCL collected 15 km. away from thermal plant) to 79.20 (GNDTP, sewerage water).

Mean Uranium concentrations in GNDP, Bathinda drinking water was 5.78 $\pm$ 0.05 ppb and 1.36 $\pm$ 0.005 ppb in TSPCL, Mansa. Mean Uranium concentrations in cooling tower water was 7.61 $\pm$ 0.447 ppb for GNDP, Bathinda and 2.36 $\pm$ 0.02ppb for TSPCLMansa, like this mean Uranium concentrations in sewerage water was 79.20 $\pm$ 3.71ppb from GNDP, Bathinda and 2.43 $\pm$ 0.01 ppb in TSPCL, Mansa. All drinking water in permissible range according to WHO guideline and safe for drinking purpose.

1) **Guru Nanak Dev Thermal Plant, Bathinda:**

The Uranium concentration in different water samples ranged from 3.68 $\pm$0.04 - 79.20 $\pm$ 3.71ppb Values for minimum and maximum uranium concentrations 3.68 ppb is found 15 km. away thermal plant and maximum (76.499ppb) were found in sewerage water from thermal plant area, respectively in GNDP. In drinking water of water works water (without purified) raw water have 51.60ppb uranium, which is above permissible unit given by WHO. Handpump water has 8.67 ppb uranium it is safe for drinking purpose. Like this purified water either through aquaguard or RO treated water inside thermal plant uranium concentrated estimated 5.78ppb is in permissible range. But continuous use of this water may cause serious problem to plants and human beings, so necessary treatment of water is required before it use.

2) **Talwandi Sabo Power Cooperation Limited, Mansa**

The Uranium concentration in different water samples ranged from (1.10 $\pm$0.01) to (2.43 $\pm$ 0.01) ppb. Values for minimum and maximum uranium concentration (1.10 ppb and 2.43ppb) were found for away from thermal plant and in sewerage water in TSPCL, respectively. These all samples are in permissible range and safe for public use. Its limited concentration does not affect harm to plants and animals.

It is relevant to indicate that the World Health Organization prescribes 15 ppb as a standard for uranium in drinking water. Computing to this prescribed level, 20% drinking water samples exceeded the permissible limits. The mean Uranium concentration for the control water sample was negligible. Which is low compared with the observed uranium concentration in water samples collected both thermal plants. The result indicates an elevation of Norm content due to thermal plant establishment or any other reasons in that area like access use of fertilizers and industrialization. This could be detrimental to health of individuals exposed to these radiations.

Caesium concentration is very low in both thermal plants. Cd, Hg and Ag are found in negligible concentrations. Pb is found in range of 6.80 to 9.30 ppb it is higher than permissible range.

As is found in very high concentration. Its range in both thermal plants is 4.78 to 20.57ppb and it is not safe for drinking purpose. Like this chromium is found minimum (3.37) and maximum (10.37), Ni range in these thermal plant as shown in table is 2.81 to 10.60ppb.Cu concentration is also high in these area.

S.No.	*Water Source*	*Uranium concentration (ppb)*	*Cesium concentration (ppb)*
WA1	*Drinking Water*	*5.78 $\pm$ 0.05*	*0.45 $\pm$ 0.001*

WA2	***Hand pump Water***	***8.67 ± 0.40***	***0.10 ± 0.001***
WA3	***Cooling Tower Water***	***7.61 ± 0.44***	***0.37 ± 0.001***
WA4	***Sewerage water***	***79.20 ± 3.71***	***0.12 ± 0.005***
WA5	***Water works water (Raw Water)***	***51.60 ± 0.32***	***0.11 ± 0.005***
WA6	***15 Km away from thermal plant***	***3.68 ± 0.04***	***0.65 ± 0.001***

Table 1.Uranium and Cesium concentration in Guru Nanak Dev Thermal Plant, Bathinda.

S.No.	***Water Source***	***Uranium concentration (ppm)***	***Cesium concentration (ppb)***
WB1	***Drinking Water***	***1.36 ± 0.005***	***0.18 ± 0.005***
WB2	***Hand pump Water***	***2.02 ± 0.01***	***0.12 ± 0.005***
WB3	***Cooling Tower Water***	***2.36 ± 0.02***	***0.24 ± 0.005***
WB4	***Sewerage water***	***2.43 ± 0.01***	***0.11 ± 0.005***

WB5	***Water works water (Raw Water)***	***2.40 ± 0.18***	***0.11 ± 0.001***
WB6	***15 Km away from thermal plant***	***1.10 ± 0.01***	***0.10 ± 0.005***

Table 2. Uranium and Cesium concentration in Talwandi Sabo Power Cooperation Limited, Mansa

7. CONCLUSION

This study investigates two thermal power plants located in the Indian state of Punjab, namely the Guru Nanak Dev Thermal Plant (GNDTP) situated in Bathinda and the Talwandi Sabo Power Cooperation Limited (TSPCL) located in Mansa. This research is centred on examining the ecological ramifications of said plants, encompassing the effects of thermal, soil, water, and air pollution. Both of the aforementioned plants employ coal as a means of generating power, thereby leading to the generation of fly ash, a residual substance that is abundant in heavy metals and radionuclides. These substances have the ability to blend with the surroundings and have an impact on the flora, fauna, and human beings.

The research utilises the analytical technique of Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) to assess the levels of radionuclides and heavy metals present in diverse specimens. The aforementioned technique presents multiple advantages, including but not limited to reduced detection thresholds, minimal utilisation of samples, and limited spectral interferences. The method has demonstrated notable efficacy in ascertaining the concentrations of uranium, cesium, and heavy metals.

The analysis of water samples indicated a notable concentration of uranium, surpassing the established safety thresholds as stipulated by the World Health Organisation (WHO). The concentration of uranium in untreated water was found to be significantly elevated, underscoring the necessity of implementing a purification process prior to utilisation. Nevertheless, the levels of cesium were found to be within acceptable thresholds. The results indicate that GNDTP, Bathinda exhibited comparatively elevated average levels of uranium, cesium, and heavy metals in the collected water samples, when compared to the other plant.

The persistent issue of heavy metal contamination in water that is distributed and discharged is a matter of significant concern. The research highlights the necessity of implementing efficient and financially feasible technologies for the treatment of water and wastewater, in order to guarantee the provision of potable water and to mitigate any adverse environmental effects. All drinking water samples were found to have Biochemical

Oxygen Demand (BOD) within acceptable limits, suggesting a relatively low level of organic pollution. The levels of biochemical oxygen demand (BOD) present in the sewerage water were found to be elevated, indicating a notable degree of contamination.

The results of the soil analysis indicated that GNDTP, Bathinda had a higher concentration of radionuclides and heavy metals in comparison to TSPCL, Mansa. Furthermore, the significance of depth was paramount, as the concentration of said substances was found to be two to four times higher in deeper soil layers in comparison to those in the upper layers. The research findings have revealed an increased level of uranium concentration in fly ash specimens collected from GNDTP, Bathinda. This indicates a plausible threat to the wellbeing of the general public due to the dissemination of radioactive components through the medium of air and water.

The investigation comprised an examination of eight distinct botanical taxa cultivated in the vicinities adjacent to the thermal power facilities. The findings of the study suggest that the plants in close proximity to GNDTP, Bathinda exhibit a greater concentration of heavy metals and uranium, indicating their propensity to accumulate a higher amount of heavy metals and radionuclides from the soil. Elevated concentrations of said substances elicited alterations in the physical characteristics of flora, such as diminished levels of chlorophyll and the accumulation of fly ash. Notwithstanding the unfavourable impacts, these botanical specimens may prove advantageous for phytoremediation purposes owing to their aptitude for assimilating heavy metals from the soil.

To sum up, the study emphasises the ecological risks associated with the combustion of coal in thermal power stations. The report advocates for various measures, including the installation of underground lining in ash ponds to mitigate the risk of ash seepage into soil and groundwater. Additionally, it suggests the reduction of coal ash content and the relocation of thermal power plants from densely populated regions. The research additionally posits that the elevated levels of uranium present in Bathinda could potentially be attributed to the presence of granitic rock formations in adjacent areas that are rich in radioactive materials, or to the activities of the thermal power plant in the vicinity. The importance of conducting in-depth research utilising advanced analytical methods to determine the exact factors contributing to the elevated levels of uranium is underscored.

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