

Assessment of Heavy Metal Concentrations in Condensate from Selected Air Conditioners at Ofrima, Senate Building and Library, University of Port Harcourt

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DOI: <http://doi.org/10.38177/AJBSR.2024.6314>



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Article Received: 15 July 2024

Article Accepted: 16 September 2024

Article Published: 19 September 2024

ABSTRACT

The heavy metal content of condensate from air conditioners in Ofrima, the Senate Building, and the University of Port Harcourt Library was evaluated. The primary objective was to determine the concentrations of Lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), and zinc (Zn) in condensate samples and compare these with WHO permissible limits. AC water samples were collected using amber bottles to prevent contamination and analyzed with a flame atomic absorption spectrophotometer (Model: S4=71096) following a wet digestion method using sulfuric acid, nitric acid, and perchloric acid. Results indicated that the levels of Lead (Pb), cadmium (Cd), chromium (Cr), and iron (Fe) in all samples exceeded the guidelines established by the World Health Organization (WHO): Pb ranged from 0.016 mg/L to 0.085 mg/L, Cd from 0.002 mg/L to 0.357 mg/L, Cr from 1.345 mg/L to 4.677 mg/L, and Fe from 2.310 mg/L to 4.677 mg/L. Zn concentrations were below permissible limits except in the Ofrima sample, which was 3.142 mg/L. These heavy metals, particularly Pb and Cr, indicate that the condensate water is unsuitable for drinking. However, it may be used for non-potable purposes such as cleaning laboratory glassware, cleaning laboratories, and watering plants, especially during peak dry seasons with water shortages. The study concludes that while AC condensate water poses health risks if consumed, it has potential uses in specific non-drinking applications, particularly in water-scarce regions. Further research is recommended to assess the microbial content and variability across air conditioning units.

Keywords: Air conditioning; Condensate water; Heavy metals; Water quality; WHO guidelines; University of Port Harcourt.

1. Introduction

Water, the so-called universal solvent, is an essential finite resource but often renewable in many parts of the Earth. Around 2% of Earth's water is found in glaciers and ice caps, with the remaining percentage in the oceans. Humans can consider this unsuitable because of inaccessibility and salinity. At any point, just 0.001% of Earth's water is held within the atmosphere [1]. A comprehensive survey on technologies for extracting liquid water from the air was conducted in the early 2000s. The survey looked at different methods, such as surface cooling below the air's dew point by inducing convection or desiccants [1]. These methods promise future development, especially in adapting commercial and industrial dehumidification technologies. Recent patents have been for extracting water from humid atmospheres [2]. These inventions use hygroscopic substances, adsorbents, and desiccants, particularly for climates with low humidity [3].

However, ensuring consistent, affordable, and sustainable drinking water supply availability is becoming more critical for small urban and rural localities. With consistent electricity generation, air conditioners (AC) could be a supplementary water source during crises, especially for displaced populations [4]. It was noted that water obtained from air condensate could meet nearly 50% of the requirements for the infrastructure studied, which a contemporary hotel exemplified [5].

The World Health Organization (WHO) suggests 150 liters per capita per day as the standard for domestic use and drinking [6]. Substantial growth in air conditioner (AC) use in industrial and residential buildings has recently

occurred. AC systems are typically designed to ensure a pleasant indoor climate for people. They are also utilized for dehumidifying and cooling spaces containing electronic equipment sensitive to heat, like power amplifiers and computer servers, and environments where artwork is displayed and stored.

Cooling systems (i.e. AC) have long been utilized globally, and there is a proposal to use the condensate water from these systems in water-saving methods, applicable both in large-scale buildings and at the individual household level. Moreover, it is suggested that water from condensation should not be regarded as refuse but rather repurposed for applications such as irrigation and cooling towers [7]. In 2017, WHO stated that the quality of water is determined by its aesthetic, chemical, biological, and physical properties. Nonetheless, using condensate water from air conditioners poses possible public health risks [6]. Heavy metals might be found in condensate water due to their interaction with the cooling coils and other components of the AC system. Condensate water can serve a variety of uses besides drinking. The limited amount of condensate collected can be used to clean laboratories, wash scientific equipment, Water potted plants in greenhouses, conduct experiments, and flush toilets [8]. It may be possible to utilize condensate water for various purposes, such as laundry operations, evaporative coolers, water features, fountains, aquariums, cooling equipment, vehicle washing, and industrial processes [9]. Also, some researchers collected and examined water from a building's AC system and investigated its ongoing treatment [10].

1.1. Study Objectives

This study assessed the concentrations of heavy metals in the condensate from selected air conditioners at Ofrima, the Senate Building, and the University of Port Harcourt Library.

The objectives of this study were to: (1) Evaluate the heavy metal content in condensate water from air conditioners at the University of Port Harcourt; (2) Compare the concentrations of heavy metals found in the condensates with WHO permissible limits for drinking water; (3) Identify potential sources of contamination in the sampled condensate water; (4) Assess the variations in heavy metal content across different buildings (Ofrima, Senate Building, and Library); and (5) Provide recommendations on the safe reuse or disposal of condensate water based on the findings.

1.2. Statement of Problem

Freshwater is becoming contaminated and limited as its usage rises due to an increase in the population; this leads to the exhaustion of conventional water sources, while water contamination worsens [11]. The growing demand for municipal, industrial, and irrigation water further exacerbates the reduction of available freshwater supplies. Climate change is significant in this complex water issue [11], leading to drought in once water-rich areas. The demand for fresh water is rising daily in large cities, resulting in a depletion of the groundwater table at a rate of about 2 to 3 meters per year. Unconventional sources have been studied and adopted in recent decades to address the shortage of fresh water. Technologies such as desalination of seawater and water extraction from the air have become interesting research areas. Some studies have developed self-sustained systems using renewable energy and hygroscopic solutions that absorb humidity from the air in arid regions [12]. Mass transfer can be enhanced through a specialized absorption string designs. The saline solution captures the water and then separates it through a solar thermal collector system combined with vacuum heating [13].

1.3. Significance of the Study

Water conservation involves carefully using and protecting water resources, encompassing the quality and quantity of water used. It is an important aspect of sustainable water use. It refers to society's utilization of water resources to support ongoing development without degrading the hydrological cycle or the dependent ecological systems [13]. Finding other sources of water is very important in maintaining the water supply.

We all agree that recycling and developing new water technology should be applied in water resource management. AC water harvesting is a useful approach to solve the problem of fresh water. Recent technological advancements have highlighted condensate AC water as a potential alternative water source. Developing a technology to recover AC condensate water is a significant step toward inefficient water resource management [14].

1.4. Scope of the Study

This study covers the heavy metal content of condensate from selected ACs at the University of Port Harcourt in Ofrima, the Senate Building, and the Library.

2. Materials and Methods

2.1. Materials

2.1.1. Apparatus

- Erlenmeyer flask
- Volumetric flask
- Glass funnel
- Whatman filter paper
- Glass pipettes
- Micropipette with disposable tips
- Vinyl gloves
- Fume cupboard
- Amber bottles
- Flame atomic absorption spectrophotometer (Model: S4=71096)

2.1.2. Reagents

- Nitric acid (HNO₃)
- Perchloric acid (HClO₄)
- Sulfuric acid (H₂SO₄)

2.2. Methods

2.2.1. Sample Collection

AC water samples were collected from Ofrima, Library, and Senate using three amber bottles. These amber bottles were labeled with masking tape to identify their locations. Amber bottles are essential for sample collection as they prevent light rays from penetrating the water, which could lead to the formation of complexes. Plastics were not used during sample collection to avoid contamination from heavy metals present in plastics.

2.2.2. Sample Preparation/Digestion

In sample preparation, the wet digestion method was used. Wet digestion involves the breakdown of organic materials (e.g., bacteria, viruses, algae) in water with the help of inorganic acids. The inorganic acids used were nitric acid, perchloric acid, and sulfuric acid.

Wet Digestion Method:

1. Mix 100 ml each of HNO_3 , HClO_4 , and H_2SO_4 .
2. Measure 10 ml of each water sample into three conical flasks.
3. Add 2 ml of the mixed acid to each water sample in the conical flasks.
4. Digest the samples in a fume cupboard containing a hot plate until white fumes appear. This process kills the organic materials, leaving only the inorganic ones.
5. Allow the samples to cool after white fumes appear.
6. Filter the cooled samples into 100 ml volumetric flasks using Whatman filter paper and a glass funnel. Use three volumetric flasks, one for each sample. Filtration is performed to obtain the digest, also called the filtrate.

2.2.3. Instrumentation

After obtaining the filtrate for each sample, they were analyzed using the flame atomic absorption spectrophotometer (Model: S4=71096). Five heavy metals were analyzed for each filtrate: lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), and zinc (Zn).

The analysis involved standardizing the flame atomic absorption spectrophotometer with each heavy metal standard. The standards for Pb, Cr, Fe, Zn, and Cd varies between 0.2 to 1.0 mg/L. After standardization, the spectrophotometer reads the sample and displays the absorbance of the metals. The absorbance of each metal was recorded, and their concentrations were determined using their respective standard curves. The standard curve is a graph of absorbance against concentration (in mg/L).

3. Results

Results for the heavy metal analysis of condensate from selected ACs in Ofrima, the Library, and the Senate area of the University of Port Harcourt are illustrated in Figures 1 to 5 and summarized in Table 1. The data were compared with WHO's (2004) permissible limits and guidelines.

Table 1. Heavy metal concentration in condensate from selected air conditioners at the University of Port Harcourt

Heavy Metal	Ofrima (mg/L)	Library (mg/L)	Senate (mg/L)	WHO (2004) (mg/L)
Lead (Pb)	0.035 ± 0.005	0.016 ± 0.003	0.085 ± 0.003	0.01
Cadmium (Cd)	0.002 ± 0.001	0.036 ± 0.004	0.000 ± 0.000	0.003
Chromium (Cr)	1.345 ± 0.023	0.670 ± 0.027	0.357 ± 0.002	0.05
Iron (Fe)	3.757 ± 0.036	2.310 ± 0.030	4.677 ± 0.026	0.3
Zinc (Zn)	3.142 ± 0.036	1.979 ± 0.008	2.536 ± 0.030	3.0

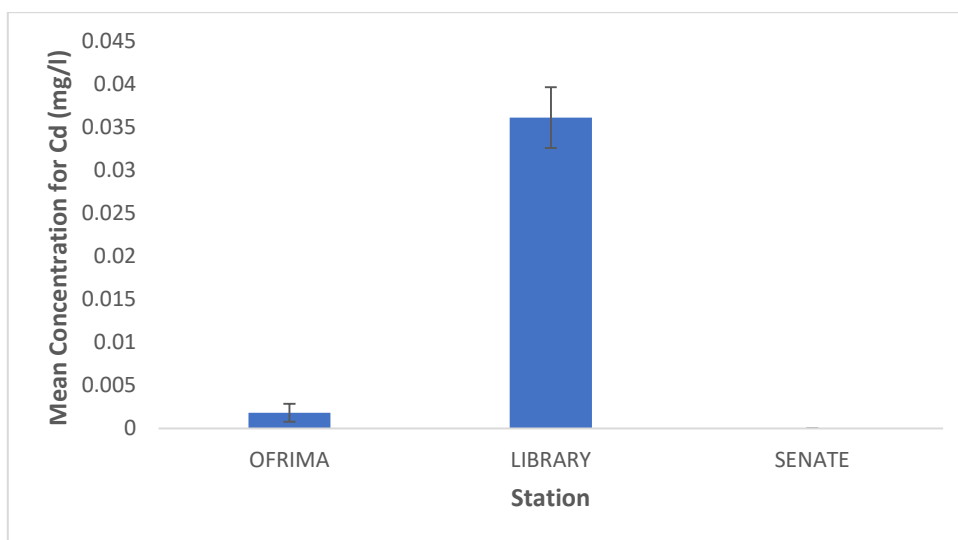


Figure 1. Cadmium concentration in condensate from selected air conditioners in Ofrima, Library, and Senate areas of the University of Port Harcourt

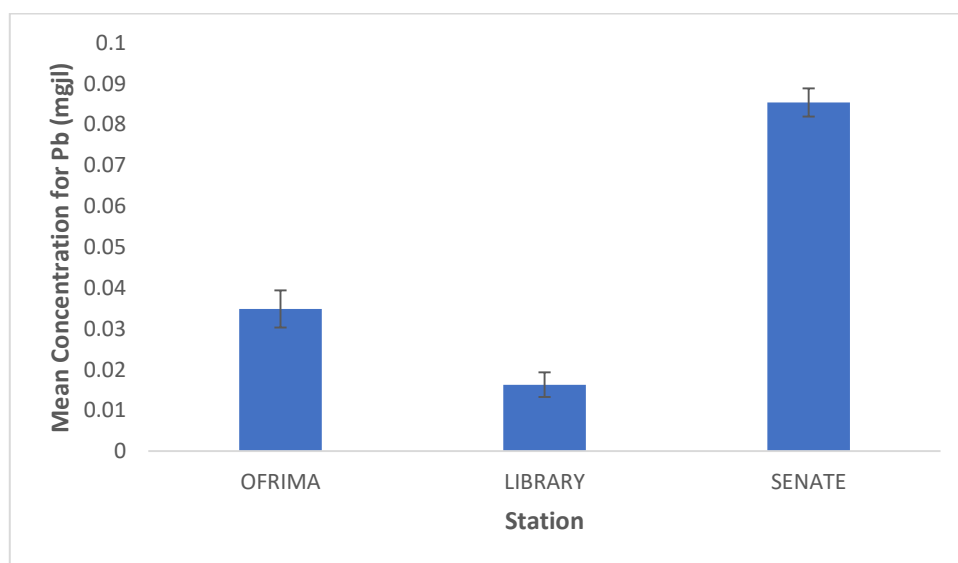


Figure 2. Lead concentration in condensate from selected air conditioners in Ofrima, Library, and Senate areas of the University of Port Harcourt

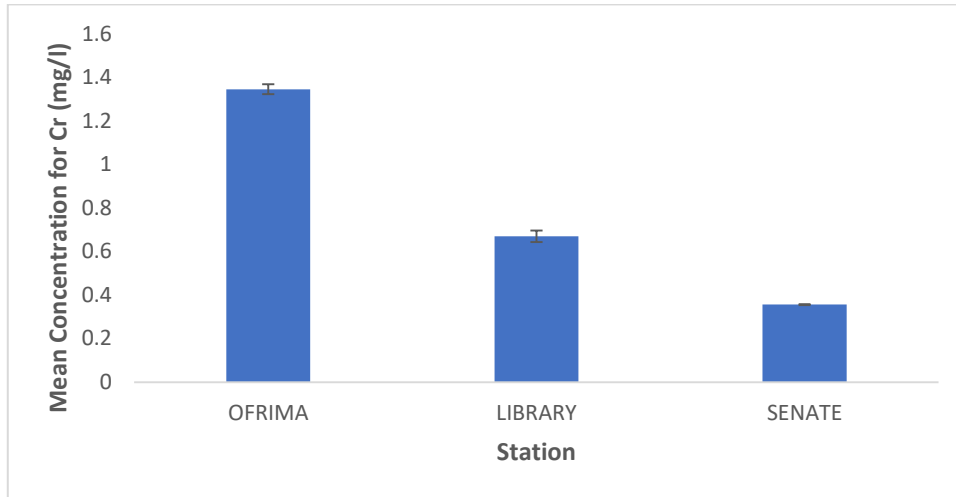


Figure 3. Chromium concentration in condensate from selected air conditioners in Ofrima, Library, and Senate areas of the University of Port Harcourt

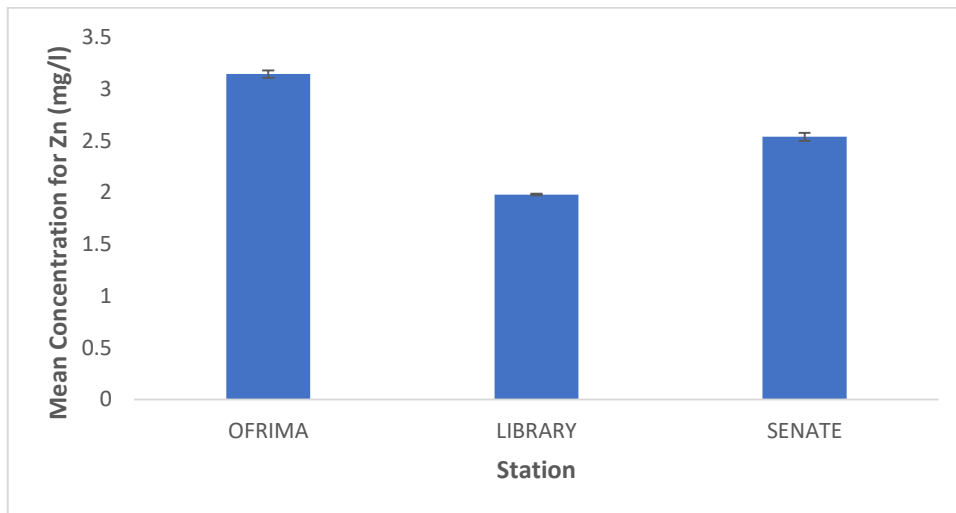


Figure 4. Zinc concentration in condensate from selected air conditioners in Ofrima, Library, and Senate areas of the University of Port Harcourt

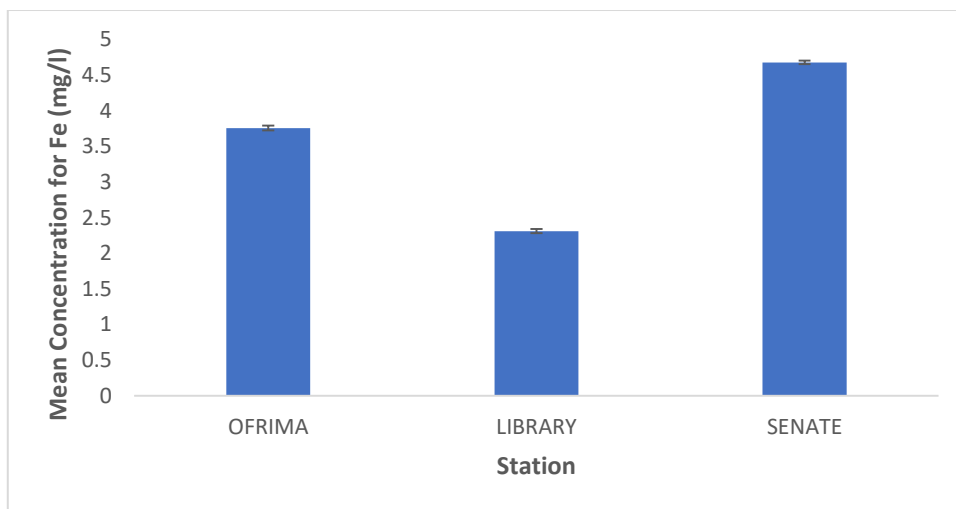


Figure 5. Iron concentration in condensate from selected air conditioners in Ofrima, Library, and Senate areas of the University of Port Harcourt

4. Discussion, Conclusion and Recommendation

4.1. Discussion

The current study investigated the heavy metal content in condensate water from air conditioners in Ofrima, the Senate Building, and the University of Port Harcourt Library. This research contributes to the broader discussion on water harvesting and conservation, particularly in regions with unique water challenges.

The results revealed that the lead (Pb) concentration in the condensate samples from Ofrima, Senate Building, and Library ranged from 0.016 mg/L to 0.085 mg/L. Notably, the Senate Building exhibited the highest lead concentration. All the condensate samples exceeded the permissible Lead limit for drinking water set by the World Health Organization (WHO), which is 0.01 mg/L [15]. This elevated concentration could be attributed to the degradation of cable coverings within the air conditioning systems, rendering the water unsafe for drinking. Lead can cause oxidative stress in various organs by disrupting membrane lipid peroxidation and reducing antioxidant defenses, highlighting potential health risks associated with its presence [16].

Cadmium (Cd) levels were also concerning. The condensate from the Senate Building exceeded the WHO guideline of 0.003 mg/L for cadmium, while the Ofrima sample had lower concentrations, and cadmium was undetectable in the Library sample. Cadmium contamination in water interferes with essential biological mechanisms, leading to acute and chronic health issues [17]. The heavy metal Cadmium (Cd) has significant environmental and occupational concerns. The International Agency for Research on Cancer (IARC) has classified it as a carcinogen for humans. Research has focused on studying the carcinogenic potential of Cd and the mechanisms underlying carcinogenesis through both in vivo animal models and in vitro cell culture. When cells are exposed to cadmium, they transform. In animal studies, the exposure to Cd has been found to result in tumors in multiple organs and tissues [18].

Chromium (Cr) concentrations in the condensate samples from Ofrima, Senate Building, and Library were significantly higher than the WHO permissible limit of 0.05 mg/L, with levels varying between 0.357 mg/L and 1.345 mg/L. Chromium, especially in its hexavalent form (Cr VI), is a common industrial pollutant. The IARC has identified it as a Group 1 occupational cancer risk [19]. Cr VI exposure has been connected to elevated mortality rates and a higher incidence of several cancers, including those of the bladder, lungs, larynx, kidney, testicles, thyroid and bones [20].

Iron (Fe) levels in the condensate samples ranged from 2.310 mg/L to 4.677 mg/L, surpassing the WHO guideline of 0.3 mg/L. The high iron content may be due to the metallic components of the air conditioning units, as iron is a prevalent metal in the Earth's crust. Iron concentrations above 0.3 mg/L could lead to laundry and plumbing fixtures staining, underscoring the potential for aesthetic and practical issues even if the water is not ingested [21].

Lastly, zinc (Zn) concentrations spanning from 1.979 mg/L to 3.142 mg/L. The Ofrima sample exceeded the WHO limit of 3.0 mg/L, while the Library and Senate Building samples were within acceptable limits. Although zinc is an essential mineral necessary for cell and tissue growth, excessive intake can cause damage to various organs, including the prostate, bones, muscles, liver, and gastrointestinal system, as noted by WHO. Zinc exposure through inhalation or ingestion of contaminated water can lead to gastrointestinal disturbances, including nausea and

vomiting. Prolonged exposure may impair immune function, leading to increased susceptibility to infections. Zinc's neurotoxic effects include symptoms like dizziness, fatigue, and headaches. Excessive zinc intake has also been associated with cardiovascular issues such as hypertension and arrhythmias [22].

4.2. Conclusion

While the heavy metal concentration in the water from the air-conditioners is above WHO permissible limits, making it unsuitable for drinking, it can still be used. The water is safe for watering potted plants in greenhouses, cleaning laboratory glassware and similar items and maintaining laboratory cleanliness during the peak dry season when water shortages are prevalent.

4.3. Recommendation

Urgent further studies are needed to critically evaluate the microbial and physicochemical properties of the study area and the differences in water condensate collected from various brands of air conditioners with the same capacity.

The following suggestions should be taken into consideration:

- (1) Expand the study to include additional buildings and facilities within the university and other institutions for a more comprehensive assessment.
- (2) Investigate the seasonal variations in heavy metal content by conducting sampling during both dry and rainy seasons.
- (3) Explore the potential health risks associated with long-term exposure to heavy metals in air conditioner condensate water.
- (4) Examine the possibility of filtering or treating condensate water to make it safe for reuse in non-potable applications, such as irrigation or cleaning.
- (5) Conduct similar studies in different geographic regions to understand how local environmental factors influence condensate water composition.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis and manuscript writing equally.

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