*Journal of Harbin Engineering University*
*ISSN: 1006-7043*
Vol 45 No. 5
May 2024

# Assessment of Heavy Metal Ions from Jawaharlal Nehru Autonagar Industrial Effluents and its Impact on Groundwater in Vijayawada

**Mr. Abhilash Nadakuditi*, Dr. Venkateswara Reddy Vangala**
[1]Research Scholar, Department of Civil Engineering, JNTUH University College of Engineering, Hyderabad, Telangana, 500 085, India.
[2]Professor, Department of Civil Engineering, JNTUH University College of Engineering, Hyderabad, Telangana, 500 085, India.

**Abstract:**
Heavy metal pollution has become a major concern in many industrial regions due to its potential harmful effects on the environment and human health. The mining, metal plating, and electronics industries generate aqueous waste containing heavy metal ions (113). If these heavy metal ions are released into the environment, they pose a serious threat to groundwater quality. Heavy metal ions may have detrimental effects on ecosystems and human health in addition to their toxicological characteristics. For the first time, the levels of some heavy metals in water in Vijayawada's Jawaharlal Nehru Autonagar industrial area (JNA) were examined by UV-Vis spectrophotometer. This analysis revealed the levels of Cr, Pb, Hg, Zn, Ni, and Cu ions in JNA industrial effluents. The analysis's findings show that the national water quality guidelines (113) for chromium (1.81-2.63), lead (0.08-0.16), and nickel (1.57-1.75) mg/L are exceeded, endangering both human health and the environment. Furthermore, the study discovered that the heavy metal ions present in the industrial effluents had a direct impact on the groundwater quality of the surrounding area. The presence of heavy metal ions in groundwater chromium (0.04-0.09) mg/L, lead (0.011-0.017) mg/L and nickel (0.037-0.06) mg/L were found to be exceed the IS 10500 drinking water standards, can have a variety of negative consequences. These effects include ecosystem degradation, biodiversity loss, and negative impacts on human health.

**Key Words**: Jawaharlal Nehru Autonagar (JNA), Industrial Sewage, Heavy Metals, Spectrophotometry, Impact on Ground Water.

## 1. Introduction:

The aim of this investigation was to examine the presence of heavy metal ions in the effluents discharged by industrial effluents and their effects on groundwater in the surrounding area. This research aimed to assess the extent of heavy metal ion contamination in the industrial effluents of the JNA area and to evaluate the impact of this contamination of groundwater quality. Heavy metal pollution is a growing concern globally due to its toxicological properties and potential impacts on human health and the environment. Many heavy metals, such as chromium, lead, mercury, zinc, nickel and copper have been found in the industrial effluents of JNA, resulting from various industrial activities such as mining, metal plating, and electronics. These heavy metal ions have the potential to contaminate groundwater sources and pose a risk to human health and the environment (112). The contamination of groundwater with heavy metal ions from industrial effluents can have severe consequences. Heavy metal contamination in groundwater can lead to various adverse effects on ecosystems and human health. These effects include the loss of biodiversity, as heavy metal ions can disrupt the balance of ecosystems and harm organisms living in water bodies.

Furthermore, heavy metal ions can accumulate in the food chain, leading to the bioaccumulation and biomagnification of these toxic substances in organisms higher up the food chain, including humans (113). The presence of heavy metal ions in industrial effluents and their subsequent contamination of groundwater sources raise concerns for the health and well-being of the surrounding communities (112). Industrial, agricultural, mining, and waste disposal activities have the potential to leach heavy metals into groundwater (113). These heavy metal contaminants are toxic and can have serious effects on biodiversity and human health. Not only can heavy metal contamination in groundwater result in land degradation on a regional scale, but it can also directly and indirectly impact the health of fauna, flora, and humans (112). Furthermore, heavy metals from corrosion products in soils can enter groundwater through colloid-assisted and soil-water transport (112). Groundwater contamination by heavy metal ions from industrial effluents, such as those in the JNA area, has led to increased concerns about potential health risks and the need for remediation measures (112). The heavy metal ions found in industrial effluents, such as chromium, lead, mercury, zinc, nickel and copper have the potential to cause various health issues in humans.

**2. Literature Review**

In a study conducted by 112, the levels of heavy metals including copper, cadmium, manganese, nickel, zinc and lead were analyzed in the soils surrounding two clusters of auto mechanic workshops in Central Nigeria. The aim of this study is to assess the possible effects on the environment of these metals. The findings revealed that the concentrations of these metals in the soils exceeded background levels and the permissible limits established by certain countries. It was observed that Gboko had a higher accumulation of metals compared to Apir. The mobility of these metals was influenced by factors such as pH, cation exchange capacity, organic matter content, and soil texture. The study concluded that the areas were highly polluted with lead and copper, moderately polluted with cadmium and manganese, and not polluted with zinc.

A study conducted by 112 in Okitipupa, Nigeria, investigated the presence of heavy metals in soil samples collected from auto-mechanic workshops. The study found that the workshops generated waste containing hazardous materials. Soil samples were collected at different depths from four workshops and analyzed for ten different heavy metals. The concentrations of heavy metals in the soil varied, with iron being the most prevalent. The study concluded that the workshop area was moderately contaminated, but the levels of heavy metals were below the permissible limit set by the DPR for soil. The researchers recommended that a separate area be designated for auto-mechanic workshops in Okitipupa.

112conducted a study to determine the levels and potential harmful effects of heavy metals in wastewater from the Eastern industrial zone in Central Ethiopia. They collected samples from different distances from the discharge point and used a wet digestion procedure to analyze the heavy metals (Cr, Cd, Zn, Fe, Pb and Cu). The validation of their procedure showed good recovery rates. The results revealed high concentrations of heavy metals, exceeding the recommended limits set by the WHO and FAO. The researchers recommend that relevant authorities take action to clean up the contaminated wastewater.

In a recent publication authored by 112, titled "Heavy metals in wastewater and sewage sludge from selected municipal treatment plants in Eastern Cape province, South Africa," an extensive investigation was conducted to examine the occurrence and distribution of five prominent heavy metals - cadmium, lead, copper, zinc, and iron - throughout the treatment process in three distinct sewage treatment facilities and the water bodies they discharge into in the Eastern Cape province. Over a period of six months, spanning from September 2015 to February 2016, samples of both liquid and solid (sludge) components were meticulously collected on a monthly basis and underwent rigorous preparation before being analyzed using atomic absorption spectrometry. The concentration levels of heavy metal ions detected in the sludge exhibited a range from concentrations below the limit of detection to 1.17 mg/kg.

In their study, 113 sought to determine the chemical forms of heavy metals present in sewage sludge from wastewater treatment plants. This is important in order to evaluate the ecological risk associated with using the sludge in agriculture or natural environments. The researchers used various methods to measure the concentrations of seven heavy metals and analyze their chemical forms. Sludge samples were collected from five plants in an industrial area in southern Poland. Various ecological risk factors were calculated to assess the risk posed by the heavy metals. The study found that Zn, Cd, and Ni had the highest ecological risk based on their chemical forms, while Cd and Hg had the highest risk based on their total concentrations. The study also found a correlation between the concentrations of heavy metals, suggesting a common source of pollution. Overall, the study highlights the importance of considering the chemical forms of heavy metals in assessing their ecological risk.

## 2. Methods:

### 2.1 Study area:

JNA, established more than half a century ago, is slowly being affected by a dirty environment and increased pollution. The main drainage system in the area has become blocked with non-biodegradable trash and dangerous waste from factories, causing a bad smell. The drains throughout JNA are also in bad condition, with many of them blocked because they haven't been cleaned in a long time. The harmful chemicals from the factories are getting into the drains, which is a big health risk for the community. JNA used to be a famous place for making trucks, fixing tires, repairing engines, and other car-related services. It has about 1,200 big and small businesses and employs around 150,000 people. But now, because of the dirty conditions and pollution, JNA is losing its good reputation. Even though it makes a lot of money, the sanitation problem has been going on for a long time.



**Figure 1. India Map showing Location of the sample collection at Jawaharlal Nehru Autonagar, Vijayawada**

The results of the study indicated that the JNA industrial effluents were a significant source of heavy metal ions and were contributing to the contamination of groundwater in Vijayawada. The presence of heavy metal ions in industrial effluents and their subsequent impact on groundwater in the JNA area of Vijayawada raises serious concerns about the potential health risks associated with heavy metal pollution. The contamination of groundwater with heavy metal ions from industrial effluents poses a significant threat to human health and the environment (113). Heavy metals such as Chromium, Lead, Mercury, Zinc, Nickel And Copper were found to be present in significant concentrations in the industrial effluents from the JNA area (113).

### 2.2 Sampling:

A total of 210 samples were collected from various outlets of the effluent stream flow from the JNA, Vijayawada, in three seasons during summer (April), rainy (August), and winter (December) 2022. 150 groundwater samples were collected from the JNA surrounding the residential area. The underlying premise guiding the endeavor is to ensure comprehensive geographic representation within the designated region. High quality polyethylene bottles with tight caps were utilized to store the samples. Prior to usage, the bottles underwent a cleaning process using distilled water and were later rinsed with 10% (v/v) nitric acid overnight. The samples were filtered using Whatmann filter paper number 42. Subsequently, the samples were promptly transferred to the laboratory in iceboxes and kept in an incubator at a temperature of 20°C, and subsequently analyzed.

As the sewage samples were collected in different seasons at various outlets, they were named, as shown in table 1. For illustration, SO1S1 is sewage sample 1 collected at outlet 1 in summer. 210 samples were collected overall, as 70 samples in the summer followed by other two seasons (10 at each outlet of 7 streams).

The ground water samples collected in different seasons from JNA surrounding residential areas and the samples were named like shown in table 2. For an illustration $SGW_1$-ground water sample 1 collected in summer. 150 were collected overall, with 50 samples in the summer followed by the other two seasons (50 in each season).

**Table 1. Identification of sewage samples were collected in different seasons**

| Season | Outlet | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Summer | 1 | $SO_1S_1$ | $SO_1S_2$ | $SO_1S_3$ | $SO_1S_4$ | $SO_1S_5$ | $SO_1S_6$ | $SO_1S_7$ | $SO_1S_8$ | $SO_1S_9$ | $SO_1S_{10}$ |
| | 2 | $SO_2S_1$ | $SO_2S_2$ | $SO_2S_3$ | $SO_2S_4$ | $SO_2S_5$ | $SO_2S_6$ | $SO_2S_7$ | $SO_2S_8$ | $SO_2S_9$ | $SO_2S_{10}$ |
| | 3 | $SO_3S_1$ | $SO_3S_2$ | $SO_3S_3$ | $SO_3S_4$ | $SO_3S_5$ | $SO_3S_6$ | $SO_3S_7$ | $SO_3S_8$ | $SO_3S_9$ | $SO_3S_{10}$ |
| | 4 | $SO_4S_1$ | $SO_4S_2$ | $SO_4S_3$ | $SO_4S_4$ | $SO_4S_5$ | $SO_4S_6$ | $SO_4S_7$ | $SO_4S_8$ | $SO_4S_9$ | $SO_4S_{10}$ |
| | 5 | $SO_5S_1$ | $SO_5S_2$ | $SO_5S_3$ | $SO_5S_4$ | $SO_5S_5$ | $SO_5S_6$ | $SO_5S_7$ | $SO_5S_8$ | $SO_5S_9$ | $SO_5S_{10}$ |
| | 6 | $SO_6S_1$ | $SO_6S_2$ | $SO_6S_3$ | $SO_6S_4$ | $SO_6S_5$ | $SO_6S_6$ | $SO_6S_7$ | $SO_6S_8$ | $SO_6S_9$ | $SO_6S_{10}$ |
| | 7 | $SO_7S_1$ | $SO_7S_2$ | $SO_7S_3$ | $SO_7S_4$ | $SO_7S_5$ | $SO_7S_6$ | $SO_7S_7$ | $SO_7S_8$ | $SO_7S_9$ | $SO_7S_{10}$ |
| Rainy | 1 | $RO_1S_1$ | $RO_1S_2$ | $RO_1S_3$ | $RO_1S_4$ | $RO_1S_5$ | $RO_1S_6$ | $RO_1S_7$ | $RO_1S_8$ | $RO_1S_9$ | $RO_1S_{10}$ |
| | 2 | $RO_2S_1$ | $RO_2S_2$ | $RO_2S_3$ | $RO_2S_4$ | $RO_2S_5$ | $RO_2S_6$ | $RO_2S_7$ | $RO_2S_8$ | $RO_2S_9$ | $RO_2S_{10}$ |
| | 3 | $RO_3S_1$ | $RO_3S_2$ | $RO_3S_3$ | $RO_3S_4$ | $RO_3S_5$ | $RO_3S_6$ | $RO_3S_7$ | $RO_3S_8$ | $RO_3S_9$ | $RO_3S_{10}$ |
| | 4 | $RO_4S_1$ | $RO_4S_2$ | $RO_4S_3$ | $RO_4S_4$ | $RO_4S_5$ | $RO_4S_6$ | $RO_4S_7$ | $RO_4S_8$ | $RO_4S_9$ | $RO_4S_{10}$ |
| | 5 | $RO_5S_1$ | $RO_5S_2$ | $RO_5S_3$ | $RO_5S_4$ | $RO_5S_5$ | $RO_5S_6$ | $RO_5S_7$ | $RO_5S_8$ | $RO_5S_9$ | $RO_5S_{10}$ |
| | 6 | $RO_6S_1$ | $RO_6S_2$ | $RO_6S_3$ | $RO_6S_4$ | $RO_6S_5$ | $RO_6S_6$ | $RO_6S_7$ | $RO_6S_8$ | $RO_6S_9$ | $RO_6S_{10}$ |
| | 7 | $RO_7S_1$ | $RO_7S_2$ | $RO_7S_3$ | $RO_7S_4$ | $RO_7S_5$ | $RO_7S_6$ | $RO_7S_7$ | $RO_7S_8$ | $RO_7S_9$ | $RO_7S_{10}$ |
| Winter | 1 | $WO_1S_1$ | $WO_1S_2$ | $WO_1S_3$ | $WO_1S_4$ | $WO_1S_5$ | $WO_1S_6$ | $WO_1S_7$ | $WO_1S_8$ | $WO_1S_9$ | $WO_1S_{10}$ |
| | 2 | $WO_2S_1$ | $WO_2S_2$ | $WO_2S_3$ | $WO_2S_4$ | $WO_2S_5$ | $WO_2S_6$ | $WO_2S_7$ | $WO_2S_8$ | $WO_2S_9$ | $WO_2S_{10}$ |
| | 3 | $WO_3S_1$ | $WO_3S_2$ | $WO_3S_3$ | $WO_3S_4$ | $WO_3S_5$ | $WO_3S_6$ | $WO_3S_7$ | $WO_3S_8$ | $WO_3S_9$ | $WO_3S_{10}$ |
| | 4 | $WO_4S_1$ | $WO_4S_2$ | $WO_4S_3$ | $WO_4S_4$ | $WO_4S_5$ | $WO_4S_6$ | $WO_4S_7$ | $WO_4S_8$ | $WO_4S_9$ | $WO_4S_{10}$ |
| | 5 | $WO_5S_1$ | $WO_5S_2$ | $WO_5S_3$ | $WO_5S_4$ | $WO_5S_5$ | $WO_5S_6$ | $WO_5S_7$ | $WO_5S_8$ | $WO_5S_9$ | $WO_5S_{10}$ |
| | 6 | $WO_6S_1$ | $WO_6S_2$ | $WO_6S_3$ | $WO_6S_4$ | $WO_6S_5$ | $WO_6S_6$ | $WO_6S_7$ | $WO_6S_8$ | $WO_6S_9$ | $WO_6S_{10}$ |
| | 7 | $WO_7S_1$ | $WO_7S_2$ | $WO_7S_3$ | $WO_7S_4$ | $WO_7S_5$ | $WO_7S_6$ | $WO_7S_7$ | $WO_7S_8$ | $WO_7S_9$ | $WO_7S_{10}$ |

**Table 2. Identification of groundwater samples were collected in different seasons**

| Sample | Summer | Rainy | Winter | Sample | Summer | Rainy | Winter |
|---|---|---|---|---|---|---|---|
| 1 | $SGW_1$ | $RGW_1$ | $WGW_1$ | 26 | $SGW_{26}$ | $RGW_{26}$ | $WGW_{26}$ |
| 2 | $SGW_2$ | $RGW_2$ | $WGW_2$ | 27 | $SGW_{27}$ | $RGW_{27}$ | $WGW_{27}$ |
| 3 | $SGW_3$ | $RGW_3$ | $WGW_3$ | 28 | $SGW_{28}$ | $RGW_{28}$ | $WGW_{28}$ |
| 4 | $SGW_4$ | $RGW_4$ | $WGW_4$ | 29 | $SGW_{29}$ | $RGW_{29}$ | $WGW_{29}$ |
| 5 | $SGW_5$ | $RGW_5$ | $WGW_5$ | 30 | $SGW_{30}$ | $RGW_{30}$ | $WGW_{30}$ |
| 6 | $SGW_6$ | $RGW_6$ | $WGW_6$ | 31 | $SGW_{31}$ | $RGW_{31}$ | $WGW_{31}$ |
| 7 | $SGW_7$ | $RGW_7$ | $WGW_7$ | 32 | $SGW_{32}$ | $RGW_{32}$ | $WGW_{32}$ |
| 8 | $SGW_8$ | $RGW_8$ | $WGW_8$ | 33 | $SGW_{33}$ | $RGW_{33}$ | $WGW_{33}$ |
| 9 | $SGW_9$ | $RGW_9$ | $WGW_9$ | 34 | $SGW_{34}$ | $RGW_{34}$ | $WGW_{34}$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | $SGW_{10}$ | $RGW_{10}$ | $WGW_{10}$ | 35 | $SGW_{35}$ | $RGW_{35}$ | $WGW_{35}$ |
| 11 | $SGW_{11}$ | $RGW_{11}$ | $WGW_{11}$ | 36 | $SGW_{36}$ | $RGW_{36}$ | $WGW_{36}$ |
| 12 | $SGW_{12}$ | $RGW_{12}$ | $WGW_{12}$ | 37 | $SGW_{37}$ | $RGW_{37}$ | $WGW_{37}$ |
| 13 | $SGW_{13}$ | $RGW_{13}$ | $WGW_{13}$ | 38 | $SGW_{38}$ | $RGW_{38}$ | $WGW_{38}$ |
| 14 | $SGW_{14}$ | $RGW_{14}$ | $WGW_{14}$ | 39 | $SGW_{39}$ | $RGW_{39}$ | $WGW_{39}$ |
| 15 | $SGW_{15}$ | $RGW_{15}$ | $WGW_{15}$ | 40 | $SGW_{40}$ | $RGW_{40}$ | $WGW_{40}$ |
| 16 | $SGW_{16}$ | $RGW_{16}$ | $WGW_{16}$ | 41 | $SGW_{41}$ | $RGW_{41}$ | $WGW_{41}$ |
| 17 | $SGW_{17}$ | $RGW_{17}$ | $WGW_{17}$ | 42 | $SGW_{42}$ | $RGW_{42}$ | $WGW_{42}$ |
| 18 | $SGW_{18}$ | $RGW_{18}$ | $WGW_{18}$ | 43 | $SGW_{43}$ | $RGW_{43}$ | $WGW_{43}$ |
| 19 | $SGW_{19}$ | $RGW_{19}$ | $WGW_{19}$ | 44 | $SGW_{44}$ | $RGW_{44}$ | $WGW_{44}$ |
| 20 | $SGW_{20}$ | $RGW_{20}$ | $WGW_{20}$ | 45 | $SGW_{45}$ | $RGW_{45}$ | $WGW_{45}$ |
| 21 | $SGW_{21}$ | $RGW_{21}$ | $WGW_{21}$ | 46 | $SGW_{46}$ | $RGW_{46}$ | $WGW_{46}$ |
| 22 | $SGW_{22}$ | $RGW_{22}$ | $WGW_{22}$ | 47 | $SGW_{47}$ | $RGW_{47}$ | $WGW_{47}$ |
| 23 | $SGW_{23}$ | $RGW_{23}$ | $WGW_{23}$ | 48 | $SGW_{48}$ | $RGW_{48}$ | $WGW_{48}$ |
| 24 | $SGW_{24}$ | $RGW_{24}$ | $WGW_{24}$ | 49 | $SGW_{49}$ | $RGW_{49}$ | $WGW_{49}$ |
| 25 | $SGW_{25}$ | $RGW_{25}$ | $WGW_{25}$ | 50 | $SGW_{50}$ | $RGW_{50}$ | $WGW_{50}$ |

**2.3 Materials**

The samples were then analyzed using UV-Spectrophotometer to assess the heavy metal ions present in JNA industrial effluents. The results of the study revealed significant concentrations of heavy metal ions including Chromium, Lead, Mercury, Zinc, Nickel and Copper in the industrial effluents as well as in the groundwater of the surrounding areas (112). The presence of excessive heavy metal levels in drinking water, surpassing the thresholds established by numerous esteemed national and international bodies, gives rise to a multitude of acute and chronic ailments (112).

## 3. Results and Discussions

### 3.1. Calibration curves

Initially absorbance is determined for 0, 2, 4, 6, 8, 10 ppm calibration samples. Calibration curves were prepared for Chromium, Lead, Mercury, Zinc, Nickel and Copper. Sewage samples were analyzed by varying their respective wavelengths. The calibration curves for Cr, Pb, Hg, Zn, Ni and Cu are as shown.

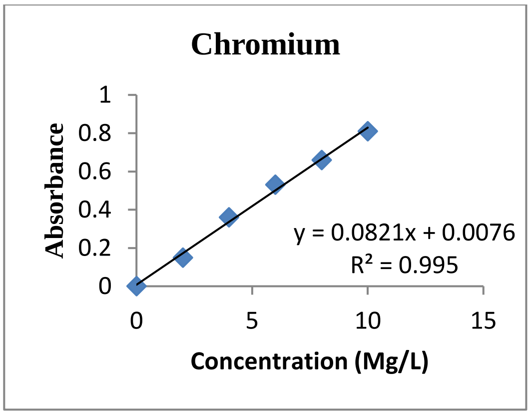



**Figure 2. Calibration curve for Chromium**

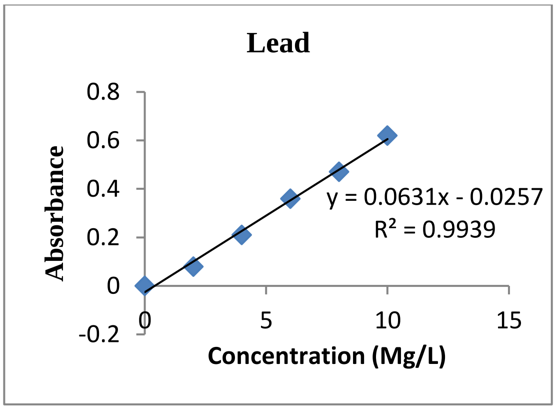



**Figure 3. Calibration curve for Lead**

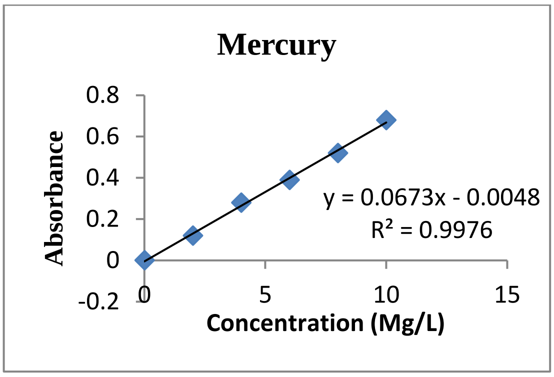



**Figure 4. Calibration curve for Mercury**

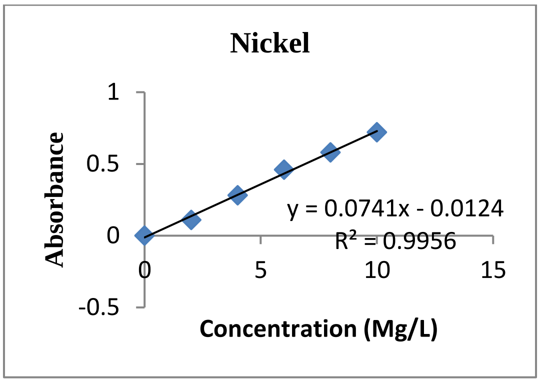



**Figure 6. Calibration curve for Nickel**

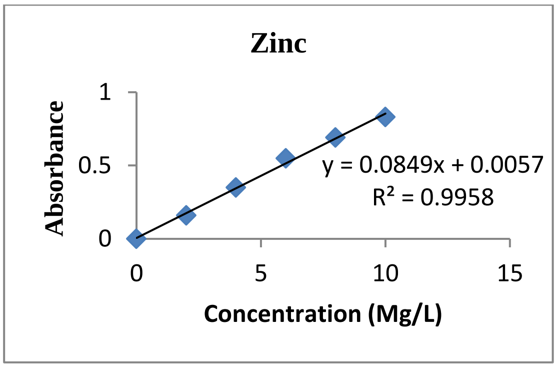



**Figure 5. Calibration curve for Zinc**

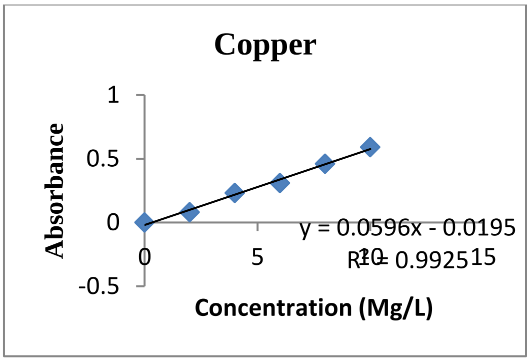



**Figure 7. Calibration curve for Copper**

**2 Analysis of samples**

The concentrations of heavy metal ions present in industrial sewage and ground water are measured from the calibration curves, as the curve drawn between concentration and absorbance. The measured concentrations of the required samples are summarized in table 3.

**Table 3. Statistical information about the levels of heavy metals in both the industrial effluents from JNA and the surrounding groundwater.**

| Sample | Parameter | Cr | Pb | Hg | Zn | Ni | Cu |
|---|---|---|---|---|---|---|---|
| Sewage (N=210) | Min | 1.8122 | 0.0881 | 0.0025 | 3.1280 | 1.5758 | 0.0256 |
| | Max | 2.6321 | 0.1645 | 0.0101 | 5.8467 | 1.7479 | 1.0076 |
| | Mean | 2.0939 | 0.1078 | 0.0067 | 4.3327 | 1.6713 | 0.4922 |
| | Standard deviation | 0.1988 | 0.0173 | 0.0022 | 0.6482 | 0.0323 | 0.2476 |
| | % RSD | 0.0950 | 0.1608 | 0.3335 | 0.1496 | 0.0193 | 0.5031 |
| Ground water (N=150) | Min | 0.0432 | 0.0110 | 0.0001 | 1.2550 | 0.0371 | 0.120 |
| | Max | 0.0933 | 0.0172 | 0.0010 | 2.0298 | 0.0605 | 0.472 |
| | Mean | 0.0675 | 0.0142 | 0.0003 | 1.7168 | 0.0518 | 0.356 |

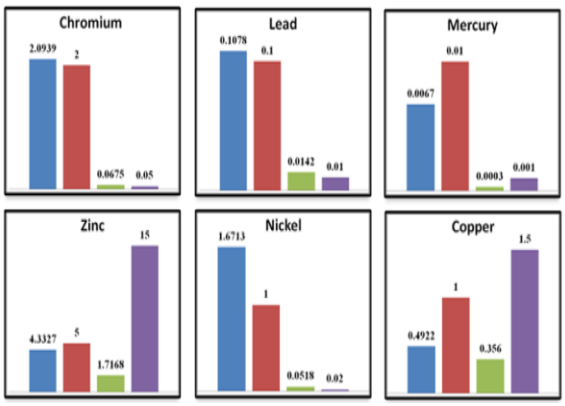
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Standard deviation | 0.0138 | 0.0019 | 0.0002 | 0.2217 | 0.0071 | 0.073 |
| | % RSD | 0.2050 | 0.1327 | 0.8626 | 0.1292 | 0.1377 | 0.205 |

### 3.3 Heavy metal concentrations vs Indian standard values

In general, the concentrations of Cr, Pb, Hg, Zn, Ni, and Cu in industrial effluents are typically below the pollution standards set by the 113. Table 4 presents the maximum allowable limits for heavy metal concentrations. However, it has been observed that the levels of Cr, Pb, Zn, and Ni in JNA exceed these pollution standards, as shown in Figure 8. The elevated levels of these metals are likely the result of human activities, such as industrial and domestic processes, which contribute to the contamination of the study area's environment. The current study also reveals that some levels of all heavy metals do not comply with the pollution standards outlined in the Environmental Protection Rules of 1986. Consequently, it can be concluded that the levels of Cr, Pb, and Ni in the groundwater of JNA and its surrounding areas are unsuitable for drinking. Furthermore, the remarkably low relative standard deviation (%RSD) observed in both groundwater and industrial effluents serves as a testament to the meticulousness and precision applied in the analysis of data pertaining to heavy metals. The wide range of levels and high %RSD of Cr, Pb, Hg, Zn, Ni, and Cu in wastewater suggest that certain locations in the study area may be significantly impacted by manmade effluents. Furthermore, the average values of heavy metal concentrations were calculated for each season, revealing that Zn consistently exhibited higher levels compared to Hg in both industrial sewage and groundwater. Additionally, the levels of Cr, Pb, and Ni in industrial effluents exceed their standard limits, as depicted in Figure 8. This comparison serves as evidence of the anthropogenic contribution of heavy metals in the study area's environment (112). To some extent, a slight increase in the levels of Cr, Pb, and Ni in the groundwater was detected, which can be attributed to a minor enrichment caused by human activities. The contamination of groundwater with Cr, Pb, and Ni is most likely a result of improper disposal of effluents from industries.

**Table 4. Indian standards for heavy metals in water (Max, allowable)**

| Parameter (mg/L) | Environmental pollutants (Environment protection rules, 1986) | Drinking water standards (is 10500-2012) |
|---|---|---|
| Cr | 2.0 | 0.05 |
| Pb | 0.1 | 0.01 |
| Hg | 0.01 | 0.001 |
| Zn | 5.0 | 15 |
| Ni | 1.0 | 0.02 |
| Cu | 1.0 | 1.5 |




Heavy metal concentrations in JNA industrial effluents

Environmental pollution standards as per Environment protection rules, 1986

Heavy metal concentrations in ground water surrounding JNA residential areas

IS 10500 drinking water standards

**Figure 8. Assessed concentrations levels vs Indian standards**

### 4. Conclusions and Future Scope

This manuscript presents the first-ever investigation of the levels of certain heavy metals in sewage and groundwater in JNA industrial area. From this investigation, the following conclusions can be made.

1. It is found that the concentrations of metal ions Mercury and Zinc are under the permissible limits where as Chromium, Lead, Nickel and Copper present in the JNA industrial sewage are high as compared with general standards for effluent discharge (113). So, it is strongly recommended for further analysis and treatment of the industrial effluent before disposal.
2. The study revealed that the groundwater near the surrounding residential areas of JNA industrial estate are free from significant enrichment by heavy metals Mercury and Zinc but Chromium, Lead, Nickel and Copper present in the ground water are high as compared with 113
3. To a certain extent, the examined residential area exhibited heightened concentrations of Fe, Cu, Zn, Cd, and Pb within its subterranean water sources.
4. The samples are collected at different seasons like summer, monsoon and spring seasons. The effluent concentration is found much higher in spring season.
5. It is recommended to conduct future studies that assess the effects on groundwater quality resulting from the improper disposal of untreated sewage, considering the physical, chemical, and microbiological factors.

**Conflicts OF Interest**

The authors have no conflicts of interest to declare.

**References**

[1] Abu Khatita Atef, Koch Roman & Bamousa Abdullah, “Sources identification and contamination assessment of heavy metals in soil of Middle Nile Delta”, Journal of Taibah University for Science, 2020, Volume 14, No 1, Pages 750–761.

[2] Adebayo Alaba Joseph, Jayoye J. Titilope, Ilemobayo Ifedayo Oguntimehin and Labunmi Lajide, “Delineation of heavy metals in soils from auto-mechanic workshops within Okitipupa, Ondo State, Nigeria”, International Research Journal of Public and Environmental Health, 2017, Vol.4 (7), pp. 136-147.

[3] Agoro Mojeed, Adeniji Abiodun, Adefisoye Martins and O Okoh Omobola, “Heavy Metals in Wastewater and Sewage Sludge from Selected Municipal Treatment Plants in Eastern Cape Province, South Africa” Water, 2020, Volume 12 (2746), Pages 1-19.

[4] Aloysius A. Pam, Rufus Sha’Ato and John O. Offem, “Evaluation of heavy metals in soils around auto mechanic workshop clusters in Gboko and Makurdi, Central Nigeria”, Journal of Environmental Chemistry and Ecotoxicology, , 2013, Vol. 5(11), pp. 298-306.

[5] Anubhav Singh, Anuj Sharma, Rohit K. Verma, Rushikesh L. Chopade, Pritam P. Pandit, Varad Nagar, “Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms”, The Toxicity of Environmental Pollutants, 2022, book chapter, Pages 1-21, *Doi: 10.5772/Intechopen.105075.*

[6] Balachandar Vellingiri, Atchaya Suriyanarayanan, Priyanka Selvaraj, Kripa Susan Abraham, Md. Younus Pasha, Harysh Winster et al., “Role of heavy metals [copper (Cu), arsenic (As), cadmium (Cd), iron (Fe) and lithium (Li)] induced neurotoxicity” Chemosphere, 2022, Volume 301.

[7] Bhagure Ganesh & Mirgane Sunil, “Heavy Metal Concentrations in Ground waters and Soils of Thane Region of Maharashtra, India”, Environmental monitoring and assessment, 2010, Volumes 173, Pages 643-652.

[8] Castro-Rodríguez JA, Holberg CJ, Wright AL, Martinez FD, “A clinical index to define risk of asthma in young children with recurrent wheezing”, American Journal Of Respiratory And Critical Care Medicine, 2000, Volume 162, Pages 1403-1406.

[9] Dagne Bekele Bahiru, “Determination of Heavy Metals in Wastewater and Their Toxicological Implications around Eastern Industrial Zone, Central Ethiopia”, Journal of Environmental Chemistry and Ecotoxicology, 2019, Volume 12(2), Pages 72-79.

[10] D. K. Todd 1980, “Groundwater Hydrology”, 2nd edition, Geological Magazine, 2009, volume 118, Pages 442.

[11] Govil PK, Reddy GLN and Krishna AK, (2001) “Contamination of soil due to heavy metals in the Patancheru industrial development area, Andhra Pradesh, India”, Journal Environmental Geology, 2001, Volume 41, Pages 461 - 469.

[12] IS 10500: 2012, "Drinking Water Specification-second revision", 2012, Pages 2-3.
[13] Malwina Tytla, "Identification of the Chemical Forms of Heavy Metals in Municipal Sewage Sludge as a Critical Element of Ecological Risk Assessment in Terms of Its Agricultural or Natural Use", International Journal of Environmental Research and Public Health (IJERPH), 2020, volume 17 (4640), Pages 1-22.
[14] Ministry of Environment and Forests, "The Environment (Protection) Rules", 1986, Page 403.
[15] Moradi Tahere, Mehraban Marzieh Adel & Moeini Mahin, "Comparison of the Perceptions of Managers and Nursing Staff Toward Performance Appraisal", Iranian Journal of Nursing and Midwifery Research, 2017, Volume 22, Pages 128-134.
[16] Redzauddin Nik, Kassim Jalina & Amir Amnorzahira, "Removal of Zinc by Nano-Scale Zero Valent Iron in Groundwater", Applied Mechanics and Materials, 2015, Volumes 773-774, Pages 1231-1236.
[17] Vinod Kumar, Shevita Pandita, Raj Setia, "A meta-analysis of potential ecological risk evaluation of heavy metals in sediments and soils", Gondwana Research, 2022, Volume 103, Pages 487-501.
[18] Xingmei Liu, Qiujin Song, Yu Tang, Wanlu Li, Jianming Xu, Jianjun Wu et al., "Human health risk assessment of heavy metals in soil-vegetable system: a multi-medium analysis", Science of the Total Environment, 2013, Volume 463-464, Pages 530-540.