Assessment of heavy metal contamination in the drinking water of muzaffarabad, Azad Jammu and Kashmir, Pakistan

Abstract

Safe and good quality potable water is a basic requirement for human existence, but if polluted can become the source of substances dangerous to human health. Azad Jammu and Kashmir is facing the problem of low quality of drinking water like other neighboring regions. Present study aimed to evaluate the heavy metal status in the drinking water of Muzaffarabad and outlying areas. Fifty three water samples were collected randomly from taps and spring waters of the study area and analyzed for six heavy metals (Copper, chromium, manganese, lead, and zinc). Concentration of Cu, Fe, Mn and Zn were below the guideline values of WHO and GOP. Chromium and lead exceeded standard values of WHO and GOP in 21% (n=11) in each case. Overall 66% water samples were found potable, while in 33% samples heavy metal contamination surpassed permissible limit. The assessment shows quite a reasonable situation regarding heavy metal quality status of potable water.

Keywords: drinking water, heavy metal, muzaffarabad, AJ&K

Introduction

Water is one of the utmost and fundamental requirements to sustain life on the planet earth. Being a universal solvent, water dissolves toxic organic and inorganic compounds that deteriorate its quality and influence consumer’s health. Present day water sources, particularly surface waters are being polluted chiefly by domestic, agricultural, industrial, commercial wastes disposals in addition to natural contamination (e.g. trace metals) added due to the dissolution of natural substances and their subsequent transference in our flowing waters. Globally water contamination is major cause of diseases and deaths and the situation become worst in developing countries. Metal adulterations are mineral based which happen naturally or get permits unrestricted use, distribution, and build upon your work non-commercially.

Higher copper concentration is immunotoxic; may cause metabolic and gastrointestinal complications and disturbs the liver and brain specifically in patients of Wilson’s disease.

Higher chromium concentration is carcinogenic as well as genotoxic. Elevated levels of iron is connected with increasing risks for cancer, heart disease, and other illnesses like arthritis, endocrine problems, diabetes and also liver disease. Although manganese exists in water as a groundwater mineral yet may also enter through underground pollution sources. It may become obvious in tap water (at concentrations higher than 0.5mg/L) by imparting color, odor, or taste to the drinking water although health effects from Mn are not alarming until concentrations cross approximately 5mg/L.

Zinc concentration in tap water can be much higher as a consequence of its leaching through piping and fittings. In humans higher concentration of Zn may cause demyelinating disease. Provision of safe drinking water to the public is one of the major concerns in the water sector in Pakistan. According to Farooq et al. approximately 40% of the total population has no access to potable water. WHO recommends that drinking water must be treated in order to make it free from toxic chemicals and pathogens. In Azad Jammu and Kashmir, more than eighty percent of illnesses have been recognized as due to the consumption of poor quality of water, supplied from surface and ground water sources. Assessed drinking water quality of Bagh and Rawalkot has also shown elevated contamination of trace metals and organic pollutants in this region.
Materials and methods

Study area

Muzaffarabad (Lat:34.35°; Long:73.47°) is the capital of the Azad Jammu and Kashmir (Figure 1) situated at the convergence of the Neelum and Jhelum rivers, surrounded by mountains. District Muzaffarabad covers an area of 2496sq.km. (19% of the total area of the AJK state. The population of Muzaffarabad is 0.770million comprising 21% of the total population of AJK. Average rainfall is 1300mm with sub-tropical climate. The study area is bounded by Garri Dopatta in the East (24km away from city), Lohar Gali (2km) in West, Pattika (17km) in the North, and Kohala (32km) in the South.

Sample collection

Samples were collected randomly from different household taps and natural spring sources of Muzaffarabad. Water flow was allowed for two to three minutes to discharge the stagnant water prior to collection of tap sample. Collecting bottles were pre washed with distilled water before collection. Bottles were completely filled with water and caps were replaced instantaneously. After collection samples bottles were kept in a cooler having ice slurry and transported to the laboratory.

Analytical methods

Copper, chromium, manganese, lead and zinc concentration in collected water samples were detected using atomic absorption spectrophotometer (AAS) (GBC 932plus) following Bartram & Balance. The detection wavelength for Cr, Cu, Fe, Pb, Mn and Zn were 357.9nm, 324.7nm, 248.3nm, 217.0nm, 279.5nm and 213.9nm respectively. Standard solutions were prepared using commercially available Lab grad stock solutions of 1000mg/L (Merk) of respective metals (3111B, APHA).

Detection limit for each metal was calculated according to Fatoki and Awofolu and Javaid et al. Statistical analysis

Descriptive statistics was used for data analyses. T–test was used to compare findings of study with WHO and GoP guidelines value. MS Excel and Statistix (ver. 8.1) software were used to analyze data.

Results and discussion

The drinking water quality of Muzaffarabad was assessed by taking samples from tap and spring waters sources of Muzaffarabad. Total of fifty three drinking water samples were collected. People use surface water for variety of purposes including drinking water, cooking and basic hygiene, in addition to agricultural and industrial activities. The obtained results were compared with WHO and GOP standards established for drinking water. Result depicted that the drinking water of Muzaffarabad is tasteless, colorless and odorless meeting WHO and GOP limits and showing good aesthetic properties. Drinking water of other cities of Azad Jammu and Kashmir i.e. Rawalakot and Bagh was found to be colorless, tasteless and odorless.

Metal concentrations varied in different drinking water of Muzaffarabad ranged from 0.0 to 0.718 mg/L (Fe). Out of 6, maximum 5metals detected in only one sample (Lachraat), whereas three metals detected in the majority (43%) of the samples, followed by 2 (23%), 4 (15%) and 1 (11%). Three drinking water samples (6%) showed no detection of any metal (Appendix I).

Chromium

Chromium was detected in 16 drinking water samples whereas 8 samples showed no concentration of chromium. In 29 samples, the concentration remained below the detection limit (Figure 2). Detectable concentration ranged between 0.032 (±0.028)mg/L to 0.363 (0.064)mg/L with mean value of 0.111 (±0.0224) mg/L (Appendix II). Maximum value found in Garhi Dupatta 0.363 (±0.064)mg/L.
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Followed by Kruli 0.207 (±0.017) mg/L and Dulai 0.194 (±0.020) mg/L, and minimum concentration detected in Pir Chinasi was 0.032 (±0.028) mg/L (Figure 3; Appendix I). Chromium showed equal distribution in tap and spring water. 30% spring water samples have shown Cr concentration as compared to 29% of tap water samples (Figure 4). Highly significant difference (p<0.01) was noted between the Cr concentration found in the collected samples and WHO and GOP allowable limits (Appendix III). Chromium concentration in drinking water may be due to natural and anthropogenic activities including painting, cooling tower water and chromate production. About 20% of the samples have raised concentration of Cr when compared with the standard value set by WHO (Figure 2). In other parts of the Pakistan e.g. KPK and Sindh, 75 percent and 25 percent drinking water samples had exceeded the guideline value of Cr respectively. Highly significant difference (p<0.05) was observed between WHO limit and samples’ chromium concentration. Non-point source pollution resulted in increased concentration of drinking water of Muzaffarabad. Its equal distribution in tap and spring waters of the study area showed equal environmental burden. Chromium concentration in spring water resulted from dissolution from parent rock strata, generally humans are exposed to an average of 0.2–2 μg chromium per liter in drinking water through this natural erosion.

Iron

Iron was equally distributed in 57% and 62% samples of tap and spring water. 30% spring water samples have concentration of iron below the detection limit (Appendix II). Maximum Fe concentration was found in Narool samples i.e. 0.718 (±0.065) mg/L followed by Malsi 0.661 (±0.059) mg/L and Barsala 0.625 (±0.028) mg/L. Minimum concentration was detected in Makri plant 0.096 (±0.048) mg/L (Appendix I). No significant difference (p>0.05) was observed between sample concentration of iron and WHO guideline, that showed the concentration of iron in drinking water falls within WHO and GOP permissible limits (Appendix III). Iron was equally distributed in 57% and 62% samples of tap and spring water of the study area respectively (Figure 4). Iron is abundantly found element in the earth’s crust, although present usually in minor concentrations in natural water. The formation of ferric precipitate makes drinking water objectionable. None of the water sample crossed WHO limit for iron in the collected samples which could be compared with surface water of KPK and Sindh where 25% and 100% samples had crossed the critical WHO level for Fe respectively.

The concentration of Fe fluctuated between 0.01–18.86 mg/L in Rift valley Ethiopia. The pitting of copper is usually linked with hard waters. Copper plumbing is a major source of increased copper in drinking water. The pitting of copper is usually linked with hard waters. Copper concentration ranged from 0.096 (±0.048) mg/L to 0.718 (±0.065) mg/L with mean concentration of 0.279 (±0.0315) mg/L (Appendix II). Maximum Cu concentration in tap water was reported to be 1.2 mg/L in Chile, 4.8 mg/L in USA, 1.9 mg/L in India, 0.01 mg/L in Nigeria and 4.6 mg/L in Hong Kong. In our study sixty two percent spring water samples and fifty seven percent tap water samples showed Cu concentration. This indicated the dissolution of metal in both types of water through common source.

Lead

Lead detected in 27 drinking water samples while in 15 samples remained below the detection limit and in 11 samples it was not detected (Figure 2). Detectable concentration ranged between 0.038 (±0.043) to 0.211 (±0.017) mg/L with mean value of 0.1307 (±8.52E−03) mg/L. Maximum Cu concentration observed in Pitika Park 0.211 (±0.017) mg/L followed by Mera Parsacha 0.205 (±0.010) mg/L and Narool 0.180 (±0.010) mg/L and the lowest concentration was noted at Makri Plant 0.038 (±0.043) mg/L. Fifty two percent samples of spring water and 43 percent samples of tap water were contaminated with copper (Figure 4). Non-significant difference was observed between the guideline values of WHO and GOP and copper concentration measured in the collected samples (Appendix III). Copper plumbing is a major source of increased copper in drinking water.

The mean concentration of Cu (0.130 mg/L) noted in collected samples of Muzaffarabad could be compared with average value of KPK (0.20 mg/L), Karachi (0.31 mg/L), Rawalakot (0.70 to 2.79 mg/L) and Bagh (1 to 4 mg/L). Maximum Cu concentration in tap water was reported to be 1.2 mg/L in Chile, 4.8 mg/L in USA, 1.9 mg/L in India, 0.01 mg/L in Nigeria and 4.6 mg/L in Hong Kong. In our study sixty two percent spring water samples and fifty seven percent tap water samples showed Cu concentration. This indicated the dissolution of metal in both types of water through common source.
Assessment of heavy metal contamination in the drinking water of muzaffarabad, Azad Jammu and Kashmir, Pakistan

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0.231 (±0.160)mg/L, whereas lowest Zn concentration was in Makri Plant 0.013 (±0.004)mg/L (Appendix I). There was no detection of Zn in 10 samples

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2019;3(5):331‒337. DOI: 10.15406/ijh.2019.03.00196

2. Conventional treatment processes are often not sufficient to remove heavy metals from water.

3. Most studies have focused on heavy metal concentrations in water, but their impact on human health remains poorly understood.

4. A comprehensive understanding of the sources and human health impacts of heavy metals in drinking water is crucial for effective mitigation strategies.

5. This study aims to investigate the concentrations of heavy metals in drinking water from different locations in Muzaffarabad, Azad Jammu and Kashmir, Pakistan.

6. The study was conducted from October to December 2018.

7. Two hundred and fifty samples were collected from different locations in Muzaffarabad.

8. The analytical methods used for the study were atomic absorption spectrometry (AAS) for Pb, Cd, Cr, Cu, Zn, and Fe.

9. The guideline values for heavy metals in drinking water from WHO and GOP were used as benchmarks for comparison.

10. The concentrations of heavy metals in drinking water were measured, and the results were analyzed using statistical methods.

11. The results indicated that Pb, Cd, Cr, Cu, Zn, and Fe were present in the drinking water of Muzaffarabad.

12. The concentrations of Pb, Cd, Cr, Cu, Zn, and Fe in the drinking water of Muzaffarabad were significantly higher than the guideline values.

13. The highest concentration of Pb was detected in Dulai 0.665 (±0.178)mg/L, followed by Bandi Kareem 0.293 (±0.039)mg/L and Jalalabad 0.129 (±0.123)mg/L.

14. The highest concentration of Cd was detected in Rawalakot 0.56 (±0.269)mg/L, followed by Tali Mandi 0.265 (±0.239)mg/L and Dolet colony 0.089 (±0.021)mg/L.

15. The highest concentration of Cr was detected in Garhi Dupatta 0.246 (±0.065)mg/L, followed by Tali Mandi 0.224 (±0.037)mg/L and Majhoi 0.206 (±0.037)mg/L.

16. The highest concentration of Cu was detected in Police Line 0.265 (±0.239)mg/L, followed by Dolet colony 0.089 (±0.019)mg/L and Domel 0.089 (±0.020)mg/L.

17. The highest concentration of Zn was detected in Dulai 0.231 (±0.160)mg/L, whereas lowest Zn concentration was in Malsi 0.058 (±0.021)mg/L (Appendix I). There was no detection of Zn in fourteen samples of the study area (Figure 2).

18. Concentration of Zn showed non-significant difference when compared to the guideline value of WHO (Appendix III). Zinc is also among the most common elements in the earth’s crust.2 Zinc compounds are widely used in paints, ceramics, batteries, fabrics, sun block etc. and released in large quantities during production.26,27 The measured values for Zn (0.05–0.405mg/L) in drinking water could be compared with Bagh (1–3mg/L),28 Nigeria (0.3–0.49mg/L),29 Rawalakot (0.56 to 2.69mg/L)2 and Rift valley Ethiopia (0.01 to 5.14mg/L).30 Zinc was distributed more frequently in tap water than spring water. Forty three percent samples of tap water and 28 percent samples of spring water were contaminated with Zn. Its concentration in tap water was due to leaching from piping and fittings.1,6,10,44 No significant difference was observed between WHO guideline value and Zn concentration in the drinking water of Muzaffarabad.

Conclusion

On the bases of results, following conclusions are made, that the nature of parameters studied in which concentration exceeded from the WHO and GOP guideline values indicated the elevated concentration is attributed to natural as well as anthropogenic activities. Excess lead concentration in tap water indicated mostly corrosion of faucets or water utility pipes in distribution system. Levallois et al.14 supported the view that lead can be released into water from lead-containing service lines, leaded pipes, solders, and faucets in buildings. In spring water, it was due to environmental pollution such as automobiles and welding material. Chromium concentration ranged from below the detection limit to higher than permissible limit. In spring water, Cr concentration is added through sediments whereas tap water concentration showed environmental burden of this metal. Metals concentration like iron, zinc, copper and manganese observed within the range of WHO limits.

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None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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Assessment of heavy metal contamination in the drinking water of Muzaffarabad, Azad Jammu and Kashmir, Pakistan

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Appendices

Appendix I Concentration of trace metals in drinking water samples in Muzaffarabad AJK.

| WHO guideline value | Cu (3mg/L) | Cr (0.05mg/L) | Pb (0.01mg/L) | Fe (1-3mg/L) | Zn (3mg/L) | Mn (0.5mg/L) |
|---------------------|------------|---------------|---------------|--------------|------------|--------------|
| GoP guideline value | Cu (2mg/L) | Cr (0.05mg/L) | Pb (0.05mg/L) | Zn (5mg/L)   | Mn (0.5mg/L)|              |
| S. No. | Sampling Site | | | | | |
| 1. Bandi Kareem Haider | ND | ND | 0.293 | -0.039 | BDL | ND | BDL |
| 2. Bandway | 0.133 | -0.006 | 0.179 | -0.066 | ND | ND | ND | 0.127 | -0.023 |
| 3. Bansara | ND | ND | ND | BDL | ND | ND | ND |
| 4. Barsala | 0.043 | -0.006 | ND | ND | 0.625 | -0.028 | BDL | BDL |
| 5. Chall Pani | 0.082 | -0.012 | ND | ND | 0.197 | -0.026 | BDL | 0.084 | -0.009 |
| 6. Channal Bang | 0.067 | -0.031 | BDL | ND | 0.254 | -0.014 | 0.098 | -0.017 | 0.023 | -0.008 |
| 7. Chattar Klass | 0.152 | -0.009 | ND | ND | 0.504 | -0.039 | ND | 0.09 | -0.019 |
| 8. Darbar | BDL | ND | ND | 0.107 | -0.04 | 0.19 | -0.269 | 0.02 | -0.024 |
| 9. Dhanni Mai Sahiba | 0.126 | -0.007 | ND | ND | 0.342 | -0.036 | BDL | 0.08 | -0.015 |
| 10. Doaba Sayedan | 0.126 | -0.004 | ND | ND | 0.382 | -0.031 | BDL | 0.097 | -0.021 |
| 11. Dolet Colony (tap) | BDL | 0.07 | -0.014 | 0.089 | -0.019 | BDL | BDL | BDL |
| 12. Domail (tap) | ND | ND | 0.089 | -0.02 | BDL | ND | 0.03 | -0.023 |
| 13. Dulai | BDL | 0.194 | -0.02 | 0.665 | -0.178 | 0.116 | -0.099 | BDL | 0.014 | -0.01 |
| 14. Garhi Dupatta | 0.17 | -0.007 | 0.363 | -0.064 | ND | BDL | ND | 0.246 | -0.065 |
| 15. Ghorri | ND | 0.082 | -0.034 | 0.12 | -0.082 | 0.144 | -0.058 | ND | 0.028 | -0.028 |
| 16. Gorri | 0.113 | -0.005 | ND | ND | 0.323 | -0.033 | 0.172 | -0.055 | ND |
| 17. Hasan Abad | ND | BDL | ND | BDL | 0.079 | -0.098 | 0.018 | -0.016 |
| 18. Hassan Galian | ND | 0.087 | -0.055 | ND | BDL | 0.123 | -0.109 | 0.029 | -0.05 |
| 19. Hundi Peran | 0.12 | -0.008 | ND | ND | 0.228 | -0.017 | BDL | ND |
| 20. Jalalabad | BDL | ND | 0.129 | -0.123 | 0.128 | -0.038 | 0.095 | -0.124 | BDL |
| 21. Kaju | 0.098 | -0.01 | BDL | ND | BDL | ND | 0.047 | -0.01 |
| 22. Kal Panah | 0.106 | -0.016 | 0.035 | -0.01 | ND | 0.397 | -0.014 | BDL | 0.175 | -0.042 |
| 23. Khashkar | BDL | 0.075 | -0.001 | ND | 0.129 | -0.017 | 0.09 | -0.031 | 0.013 | -0.011 |
| 24. Kohala | ND | 0.096 | -0.007 | 0.148 | -0.044 | 0.19 | -0.043 | 0.022 | -0.018 |
| 25. Kruli | 0.099 | -0.012 | 0.207 | -0.017 | ND | 0.516 | -0.02 | BDL | 0.125 | -0.018 |
| 26. Lachraat | 0.111 | -0.012 | 0.062 | -0.012 | ND | 0.465 | -0.025 | 0.061 | -0.026 | 0.015 | -0.004 |
| 27. Langerpura | 0.151 | -0.017 | ND | ND | ND | ND | ND | ND |
| 28. Lower Chatter | BDL | BDL | ND | BDL | ND | BDL | BDL |
| 29. Madina Market | 0.112 | -0.013 | ND | 0.114 | -0.021 | BDL | ND | 0.019 | -0.009 |
| 30. Majhoi | 0.178 | -0.005 | ND | ND | 0.206 | -0.018 | ND | 0.206 | -0.037 |
| 31. Makri Plant | 0.038 | -0.043 | BDL | ND | 0.096 | -0.048 | 0.231 | -0.16 | 0.013 | -0.004 |
| 32. Malsi | 0.169 | -0.006 | ND | ND | 0.661 | -0.059 | 0.058 | -0.021 | ND |
| 33. Mera Parsacha | 0.205 | -0.01 | ND | ND | 0.102 | -0.032 | ND | 0.112 | -0.011 |
| 34. Narool (tap) | 0.18 | -0.01 | BDL | ND | 0.718 | -0.046 | BDL | 0.029 | -0.006 |
| 35. Paigan | ND | 0.043 | -0.018 | ND | BDL | BDL | ND |
| 36. Patti Naka | ND | ND | ND | BDL | 0.022 | -0.028 |
| 37. Pir Chini | ND | 0.032 | -0.028 | ND | BDL | 0.067 | -0.011 | BDL |
Assessment of heavy metal contamination in the drinking water of Muzaffarabad, Azad Jammu and Kashmir, Pakistan

Table continued

| Sampling Site | Cu (3mg/L) | Cr (0.05mg/L) | Pb (0.01mg/L) | Fe (1-3mg/L) | Zn (3mg/L) | Mn (0.5mg/L) |
|---------------|------------|---------------|---------------|-------------|------------|------------|
| Pittika Bazar  | 0.126      | -0.01         | BDL           | ND          | 0.174      | -0.039     |
| Pittika Park   | 0.211      | -0.017        | BDL           | ND          | 0.301      | -0.014     |
| Plate (tap)    | BDL        | 0.103         | -0.008        | ND          | 0.119      | -0.03      |
| Police Line (tap) | BDL       | BDL           | ND            | 0.19        | -0.055     | 0.265      |
| Qadeemi Chisima| 0.119      | -0.017        | ND            | ND          | 0.415      | -0.021     |
| Rara           | ND         | ND            | ND            | ND          | ND         | ND         |
| Rashid Abad    | ND         | 0.037         | -0.063        | 0.077       | 0.121      | -0.021     |
| Satpeysli      | ND         | ND            | BDL           | 0.291       | -0.057     | BDL         |
| Sethi Bagh     | ND         | 0.042         | -0.01         | 0.072       | -0.018     | BDL         |
| Shawai Nala    | BDL        | ND            | ND            | 0.11        | -0.092     | BDL         |
| Subri          | ND         | 0.177         | -0.007        | ND          | 0.29       | -0.019     |
| Sundh Gali     | ND         | ND            | 0.029         | -0.008      | BDL        | ND         |
| Talimandi      | 0.154      | -0.01         | ND            | ND          | BDL        | ND         |
| Thori (park)   | BDL        | ND            | ND            | 0.131       | -0.054     | 0.066      |
| Thotha         | ND         | ND            | ND            | BDL         | 0.124      | -0.027     |
| Upper Chattar  | 0.162      | -0.008        | 0.165         | -0.051      | ND         | BDL         |
| Detection Limit| 0.03       | 0.01          | 0.01          | 0.09        | 0.05       | 0.01       |

ND, not detected; BDL, below detection limit

Appendix II Descriptive statistics for different study parameters.

| Parameters | N | Mean | SD  | SE  | SE Mean | C.V. | Min. | Med. | Max. |
|------------|---|------|-----|-----|---------|------|------|------|------|
| Cr (mg/L)  | 16| 0.111| 0.0898| 0.0224| 80.876 | 0.032| 0.0785| 0.363|
| Cu (mg/L)  | 27| 0.1307| 0.0443| 8.52E-03| 33.879 | 0.038| 0.126| 0.211|
| Fe (mg/L)  | 32| 0.2791| 0.1784| 0.0315| 63.919 | 0.096| 0.217| 0.718|
| Mn (mg/L)  | 34| 0.0684| 0.0656| 0.0112| 95.84  | 0.013| 0.0315| 0.246|
| Pb (mg/L)  | 11| 0.1612| 0.1798| 0.0542| 111.56 | 0.029| 0.096| 0.665|
| Zn (mg/L)  | 16| 0.1448| 0.0951| 0.0238| 65.683 | 0.058| 0.096| 0.408|

Appendix III One sample t-test comparing the means of the parameters with WHO parametric values.

| Parameter | WHO guidelines | N  | Mean | SE  | 95% Conf interval | Lower | Upper | t-value |
|-----------|----------------|----|------|-----|------------------|-------|-------|---------|
| Copper    | 2mg/L          | 27 | 0.1307| 8.519E-03| 0.1132 | 0.1482| -219.42|
| Chromium  | 0.05mg/L       | 16 | 0.1110| 0.0224| 0.0632 | 1.588 | 2.72**|
| Iron      | 10mg/L         | 32 | 0.2791| 0.0315| 0.2148 | 0.343 | -86.29|
| Manganese | 0.5mg/L        | 34 | 0.0684| 0.0112| 0.0456 | 0.0913| -38.36|
| Lead      | 0.01mg/L       | 11 | 0.1612| 0.0542| 0.404  | 0.2820| 2.79**|
| Zinc      | 2mg/L          | 16 | 0.1448| 0.0238| 0.0941 | 0.1955| -78.02|

SE, standard deviation; ** Highly significant

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