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Geo-spatial distribution of hydrological nephrotoxic characteristics in Kalawewa and Tissawewa reservoirs in Anuradhapura, Sri Lanka

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Abstract
Reservoirs are one of the major water resources subjected to different forms of pollution due to anthropogenic activities. Heavy metals and water hardness are a particular concern due to their potential toxic effect and bio-accumulate ability. Therefore, the objective of this investigation was to analyze the spatial distribution of selected heavy metals Cadmium (Cd), Lead (Pb), and Arsenic (As) and total water hardness in Kalawewa and Tissawewa reservoirs, Anuradhapura District in Sri Lanka. Cd, Pb, and As contents of water samples were analyzed using Inductive Coupled Plasma Mass Spectrometry (ICP-MS-Agilent-7800). Total water hardness values were analyzed based on Ca and Mg concentrations of water samples. Spatial distribution patterns of analyzed heavy metals and total water hardness values were interpolated using Inverse Distance Weighted (IDW) and Spatial autocorrelation tool in ArcMap 10.2.2 software. Overall, the mean heavy metal concentrations in two reservoirs complied with World Health Organization agricultural water standards. The mean total water hardness values of the two reservoirs reflect "very hard water", and the distributions of analyzed heavy metals and water hardness were higher in the center. As long term exposure to nephrotoxic heavy metals adversely affects human health, taking all necessary changes before consumption can be recommended.

Keywords
nephrotoxic heavy metals, reservoirs, spatial distribution, water hardness

Introduction

A water reservoir is an enclosed area for the storage of water to be used later. In most developing countries, such as Sri Lanka, most reservoirs serve as the main drinking and irrigation water source. Sediments consist of environmental toxicants such as heavy metals are stored in reservoirs, as they are subjected to different types of pollution arising from anthropogenic activities (Wang et al., 2012; Anash et al., 2019). These toxicants can be released into adjacent water columns with the environmental changes. Among various environmental toxicants, Cadmium (Cd), Lead (Pb), and Arsenic (As) are concerning as nephron-toxins since long-term exposure to these heavy metals causes chronic renal failures (Wijesinghe et al., 2018; Ekanayake and Manage. 2017; Thakeshi et al., 2015).

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Improper agricultural practices, industrial development, and rapid urbanization are significant concerns for releasing toxicants into the environment (Allan & Castillo. 2007). Extreme usage of heavy metal-containing fertilizers and pesticides in agricultural fields within the reservoirs' catchment areas is one of the major anthropogenic sources for heavy metal contamination in reservoirs. Untreated waste and partially treated effluents contaminated with toxic metals and metal chelates releasing to the catchment reservoirs is another factor that leads to an increase in the contaminant levels (Ansah et al., 2018).

In addition to various agricultural activities, the distribution and the levels of contaminants in reservoirs depend on hydrodynamic conditions, metal type, sediment sources, shape, and morphology of the reservoirs. The deposition of heavy metals is mainly associated with reservoir operation and biochemical processes. Generally, heavy metal concentrations of a reservoir varied in different sampling locations and layers and as well as due to the seasonal variations (Sojka et al., 2018).

Heavy metals are non-biodegradable, high-density metallic elements with long-lasting toxic effects. These are transferred and accumulated into the aquatic ecosystems due to mismanagement of waste containing environmental toxicants (Wijesinghe et al., 2018). Most heavy metals are toxic, and some are subjected to bioaccumulation and biomagnification (Wijesinghe and Manage. 2012). Different studies have shown that long-term exposure to low concentrations of heavy metals resulted in the development of various chronic diseases such as Chronic Renal Failures (CRF) and Chronic Kidney Disease of unknown etiology (CKDu) (Oguize and Okhagbuzo. 2009).

Sri Lanka is one of the world's major countries with the highest densities of reservoirs, and most of the reservoirs in the country are located in the dry zone (Subasinghe et al., 2012). According to past studies, CKDu prevalent areas are clustered around the reservoirs; therefore, assessing the water quality in reservoirs is necessary to determine the various levels of pollution of these water resources and the protection and development of reservoirs. The present investigation was conducted to determine the spatial distribution of environmental toxicants and water hardness levels in Kalawewa and Tissawewa reservoirs in Anuradhapura district, Sri Lanka.

According to the Ministry of Irrigation and Water Resource Management records in Sri Lanka, Kalawewa is an integrated water body, a main irrigation reservoir of the Grand Mahaweli Multipurpose Irrigation Scheme. It serves the people in the North Central region in Sri Lanka by supplying water for small tanks in rural areas. The reservoir is used for channel water to Tissawewa, Basawakkulama & Nuwarawewa reservoirs at Anuradhapura by Yoda Ela canal. Tissawewa is an artificial reservoir, and it has been built to increase the water supply to the city of Anuradhapura, Sri Lanka. Agrochemical contamination and accumulation of heavy metals are significant striking effects of pollution in these reservoirs.

Lead (Pb) can be detectable among various environmental toxicants in all phases of the inert environment and all biological ecosystems (Wijesinghe et al., 2018). According to the WHO (4th edition, 2011) and SLS standards (614:2013), the maximum permissible limit of Pb in water is 0.01 mg/L. As per the WHO (4th edition, 2011) and SLS standards (614:2013), the maximum permissible limit of Cadmium (Cd) in drinking water is 0.003 mg/L. Cd is a highly toxic non-essential heavy metal, and it causes various chronic diseases when they accumulate in the liver, bones, blood, muscles, and kidney (Castro-Gonzales et al., 2008; Shivakumar et al., 2014; Tuzen. 2009). Furthermore, it is a widespread environmental contaminant and a potential toxin that adversely affect human health. Arsenic (As) is widely found in different ecosystems. The usage of agricultural chemicals has been found as one of the major anthropogenic sources of As in aquatic ecosystems in Sri Lanka. As can exist in biotic and abiotic components of aquatic environments at various concentrations. Skin, bladder, and lung cancers

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are the significant effects caused by As in water to humans. The maximum permissible level of As in drinking water is 0.01 mg/L, according to the WHO (4th edition, 2011) and SLS standards (614:2013) (Amarasiri, 2015).

Furthermore, water hardness plays a major role in supporting heavy metals by cation exchange capacity (Wanasinghe et al., 2018). The hardness of water is due to carbonate and sulfate salts of Calcium (Ca) and Magnesium (Mg). Major impacts of the water hardness are urinary stone formation, growth retardation, reproductive failure, and other health problems such as chronic kidney damages (Sengupta. 2013). Higher hardness in drinking water restricts sufficient water uptake, affecting humans' physiological, biochemical, and nutritional requirements (Wickramarathna et al., 2017). Therefore, it is necessary to determine the water hardness levels in reservoirs as those waters use for agricultural and domestic purposes, including drinking requirements.

From the ancient irrigation history of Sri Lanka, reservoirs are the major water conveyance mechanism that has improved to overcome water requirements in dry zone (Wanasinghe et al., 2018). The usage of agrochemicals and chemical fertilizers excessively and indiscriminately without safety measures is a major problem that contaminates the reservoirs with environmental toxins. The natural aquatic ecosystems are extensively contaminated with nephrotoxic heavy metals released from domestic, industrial, and other human-made activities (Subasinghe et al., 2012). Furthermore, due to soil erosion, many of these toxicants get into water reservoirs and discharge toxic compounds that contaminate crops and cause unknown chronic diseases to the people.

During the past two decades, many patients with chronic diseases such as CKDu were reported significantly in the North Central Region in Sri Lanka. Most of these chronic diseases are suspected to be due to the nephrotoxicity induced by environmental toxicants and higher water hardness levels. Among them, toxicants ingested from water are assumed as the most reasonable risk factor for these abnormalities, and the water quality is a crucial component to indicate human health. Kalawewa and Tissawewa are the prominent reservoirs situated in North Central Region in Sri Lanka, which are utilizing for agricultural and domestic purposes from ancient Sri Lankan history. But there are no studies that have been conducted to assess the distribution of major environmental toxicants and hardness levels of these reservoirs. Therefore, this study was carried out to investigate the spatial distribution of environmental toxicants; Cadmium(Cd), Lead(Pb), Arsenic(As), and water hardness levels in Kalawewa and Tissawewa in Anuradhapura District, North Central Province, Sri Lanka.

Materials and Methods

Sample site selection and sample collection

Kalawewa and Tissawewa were selected as the study areas, which are major reservoirs in Anuradhapura district, North Central Province in Sri Lanka. Kalawewa is one of the largest irrigation tanks in Anuradhapura District (8.0116° N, 80.5577° E), Sri Lanka. Tissawewa is an artificial reservoir located in Anuradhapura District (8.3370° N, 80.3854° E), Sri Lanka (Fig. 1).

Fifteen (15) sampling locations were selected for the study according to Random Stratified Design (RSD) from both Kalawewa and Tissawewa reservoirs separately, and the sample locations were recorded at the field using Global Positioning System (GPS) coordinates.

Triplicated water samples were collected from all fifteen sampling locations of each reservoir and transferred into pre-cleaned uncontaminated Teflon bottles (125 mL) after rinsing with the water to sample and labeled. Collected water samples were acidified by adding ultrapure Nitric acid (2% v/v) (Sinopharm, Shanghai, China) (0.10 mL). These bottles were tightly closed, labeled, and transported to the CKDu Information and Research Centre, Faculty of Science, University of Kelaniya preserved in ice packs. All the collected samples were stored in a refrigerator below 4ºC temperature.

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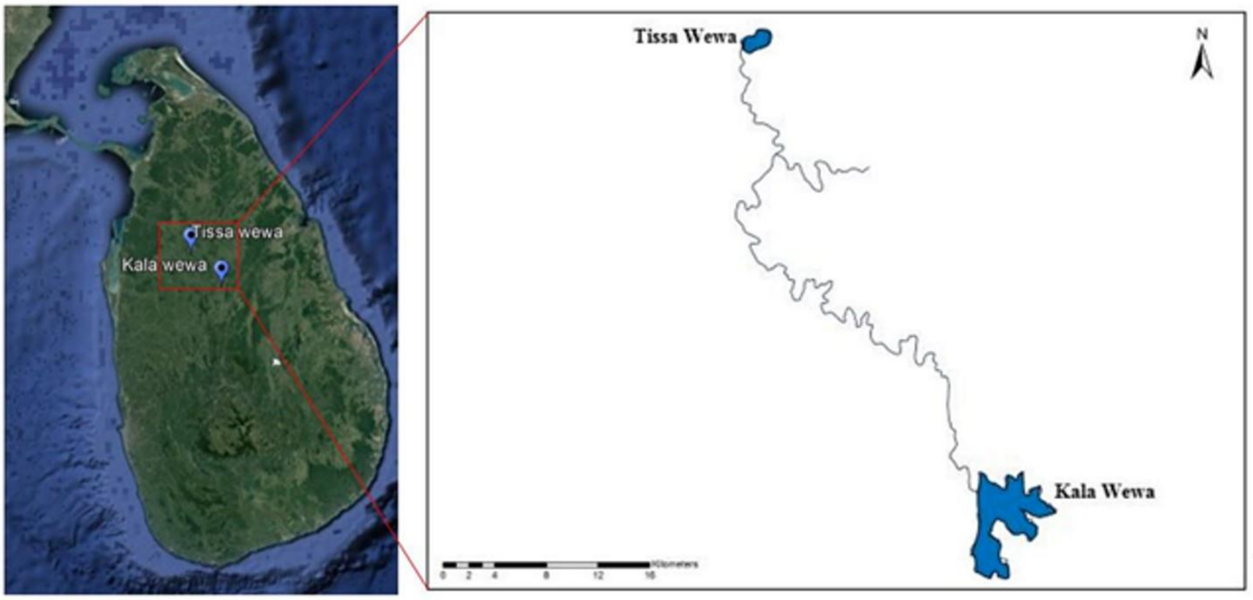

Figure 1. The map showing the Kalawewa and Tissawewa reservoirs in Sri Lanka.

Sample Analysis

Determination of Arsenic, Cadmium, Lead, Calcium, and Magnesium concentrations in water. All the collected water samples were filtered using nylon welded syringe filters (0.45 µm) before the chemical analysis. Cd, Pb, As, Mg, and Ca concentrations of collected water samples were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS-7800-Agilent, Germany) according to standard procedures. Multi-element ICP-MS standards (AccuStandard, USA) were used for instrumental calibration. Acidified water samples (with Conc. HNO_3) were filtered through 0.45µm syringe filters before the insertion to the ICP-MS instrument.

Determination of Total Hardness in water. Total hardness was measured as the number of polyvalent cations (basically of Ca^{2+} and Mg^{2+}) in water samples. The total hardness was calculated using the following formula, where the concentrations of Ca and Mg are expressed in mg/L.

$$\text{Total Hardness} = 2.5\,[Ca^{2+}] + 4.1[Mg^{2+}] \qquad [1]$$

The factors 2.5 and 4.1 are the ratios of the formula weight of calcium carbonate (100) to the weights of Ca (40) and Mg (24.3) (Amarasiri. 2015). Categorization of the total water hardness levels are shown in Table 1.

Table 1. *Water Hardness scale.*

Total water hardness	Category
>60 mg/L	Soft water
60 – 120 mg/L	Moderately hard water
120 – 180 mg/L	Hard water
<180 mg/L	Very hard water

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Data analysis and geographical data treatment
Measured heavy metal concentrations and total water hardness in Kalawewa and Tissawewa were analyzed using Minitab statistical software package by performing descriptive statistics on the data set. Geographical Information System (GIS) coordinates were used for the study to display the distribution of heavy metal concentrations and other water quality parameters in Kalawewa and Tissawewa. Point-based Inverse Distance Weighted (IDW) interpolation and spatial autocorrelation (Moran's Index - MI) tools of ArcMap 10.2.2 software were used to analyze the spatial distribution of analyzed heavy metal concentrations and total water hardness values in Kalawewa and Tissawewa.

Results and Discussion

This study was based on the measurements of selected nephrotoxic heavy metals (Cd, Pb, and As) and the total water hardness. Mean heavy metal concentrations and total water hardness results were analyzed for both Kalawewa and Tissawewa reservoirs and recorded in Table 03 and Table 04. Compared to the drinking water quality guideline values Cd, Pb, and As levels in most sampling locations in both reservoirs were below the maximum permissible levels. Considering the water hardness values in Kalawewa and Tissawewa reservoirs, almost all the water hardness values indicated a 'very hard water' level (>180).

Table 2. *Physicochemical data of reservoir water samples collected from Kalawewa in Anuradhapura District, Sri Lanka, and standard values of drinking and irrigation water.*

Parameter	Minimum	Maximum	Mean	± SD	Drinking standard			Irrigation standard
					SLS	WHO	USEPA	FAO
Cd (µg/L)	0.0026	0.2943	0.1246	0.0110	3	3	5	10
Pb (µg/L)	0.2185	1.7787	0.6838	0.0890	10	10	15	5000
As (µg/L)	0.2016	2.7097	0.9196	0.0700	10	10	10	50
Total Water Hardness (mg/L)	396.0	1040.0	508.4	191.7	>180	>180	>180	(Ca-40-100) (Mg- 30-50)

Table 3. *Physicochemical data of reservoir water samples collected from Tissawewa in Anuradhapura District, Sri Lanka, and standard values of drinking and irrigation water.*

Parameter	Minimum	Maximum	Mean	± SD	Drinking standard			Irrigation standard
					SLS	WHO	USEPA	FAO
Cd (µg/L)	0.0142	0.1625	0.0840	0.0580	3	3	5	10
Pb (µg/L)	0.5544	18.0768	4.1419	0.0591	10	10	15	5000
As (µg/L)	0.0214	3.1453	0.7506	0.0835	10	10	10	50
Total Water Hardness (mg/L)	147.00	440.00	381.27	69.18	>180	>180	>180	(Ca-40-100) (Mg- 30-50)

Spatial distribution patterns of selected heavy metals and total water hardness have been analyzed for the Kalawewa reservoir using the IDW tool and Spatial autocorrelation (Moran's Index- MI) tool in ArcMap 10.2.2 software.

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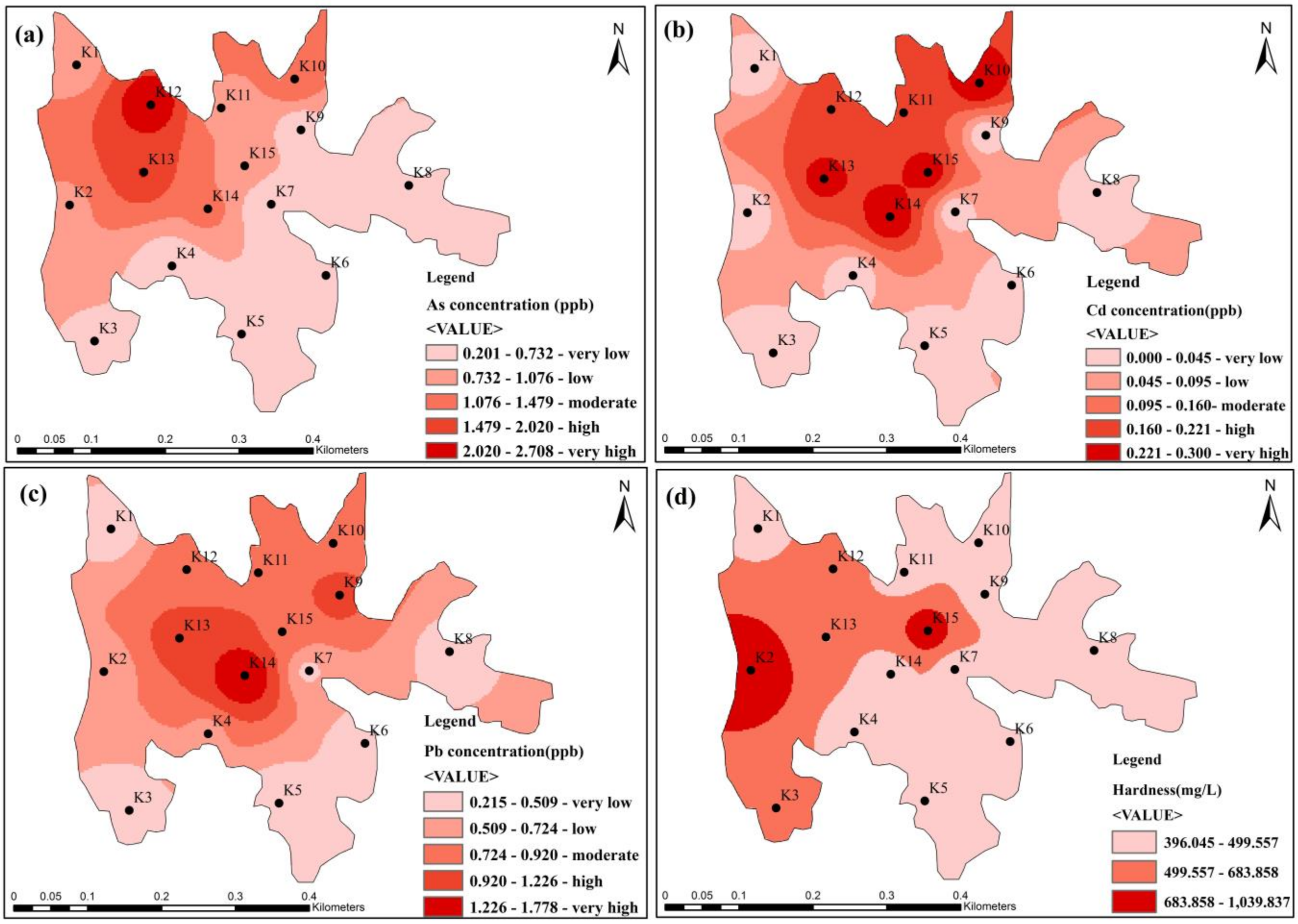

Figure 2. *Spatial distribution of (a) Arsenic, (b) cadmium, (c) Lead, and (d) Water Hardness in Kalawewa reservoir, Sri Lanka.*

Figure 2(a) shows the distribution of As in water at fifteen sampling locations in the Kalawewa reservoir. The range of As in water varied from 0.2018 μg/L to 2.7081 μg/L according to the ArcMap 10.2.2 software. The area which including seven sampling locations shows the lowest range of Arsenic (0.2018 μg/L – 0.7326 μg/L) and the highest range of Arsenic (2.0201 μg/L- 2.7081 μg/L) was demonstrated by one sampling location (k12) included area. According to the WHO, USEPA, FAO, and SLS standards for both drinking and irrigation water standards (Table 02), Arsenic content at each location in the Kalawewa reservoir was not exceeding the maximum permissible level. The highest concentrations of As were found in the south and west of the reservoir; furthermore, As levels were clustered in lower levels in the Kalawewa reservoir with Moran's Index of 0.2151.

For Cd, the highest range (0.2214 μg/L – 0.3002 μg/L) in water was recorded by four different sampling locations (k10, k13, k14, k15), a majority of them are located in the center of the Kalawewa reservoir. Cd content in the Kalawewa reservoir was ranged from 0.00001 μg/L through 0.30024 μg/L as per the ArcMap 10.2.2 software. The Northern part of the reservoir showed the highest Cd concentrations than the Southern part of the reservoir (Fig. 2(b)). According to the spatial autocorrelation report, Cd levels were clustered in lower levels in the Kalawewa reservoir with Moran's Index of 0.2846. Distributed Cd concentrations of the reservoir were not exceeding the maximum permissible level of Cd for both drinking and irrigation water, according to the WHO, USEPA, FAO, and SLS standards (Table 2).

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The Pb concentrations were ranged from 0.2155 μg/L to 1.7782 μg/L in the Kalawewa reservoir, as shown by Figure 02 (c). The reservoir's center indicated the majority of the 'very high' and 'high' Pb concentration levels compared to the shallow water columns. In addition to that, Pb levels were also clustered in lower levels in the Kalawewa reservoir with Moran's Index of 0.1940. In almost all the samples (n=15), Pb concentrations were within the maximum permissible limit considering both drinking and irrigation water (Table 02). In the Kalawewa reservoir, Pb concentrations in analyzed water samples were found to be more varied. Pb distribution demonstrated that its concentration in six samples was found within the lowest range values (0.2158 μg/L – 0.5099 μg/L).

The degree of hardness in drinking water is a major key factor for the acceptability of the consumers and operational, economic, and professional requirements (WHO Guidelines for Drinking-water Quality 2011). According to the results, total water hardness in all the analyzed water samples exhibited higher values that exceed the maximum permissible value (>180 mg/L – 'very hard water', Table 2). The spatial distribution of total water hardness values in the Kalawewa reservoir is shown in Figure 2(d), and the hardness values ranged from 396 mg/L to 1040 mg/L. Total water hardness values were higher in the west part of the reservoir than the east part of the reservoir.

The spatial distribution patterns of heavy metal concentrations and total water hardness in the Tissawewa reservoir are illustrated in Figure 3. Except for total water hardness values above the maximum permissible limit (>180), all the other mean values of analyzed heavy metal concentrations were below the maximum permissible levels according to the standard values for drinking and irrigation water samples mentioned in Table 3.

Water in the Tissawewa reservoir's center exhibited relatively higher As concentrations compared to shallow water levels (Figure 03 (a)). Considering the obtained results, As concentrations in Tissawewa reservoir waters ranged from 0.0032 μg/L to 3.1449 μg/L. Spatial distribution patterns of Cd showed its lowest concentrations in the water

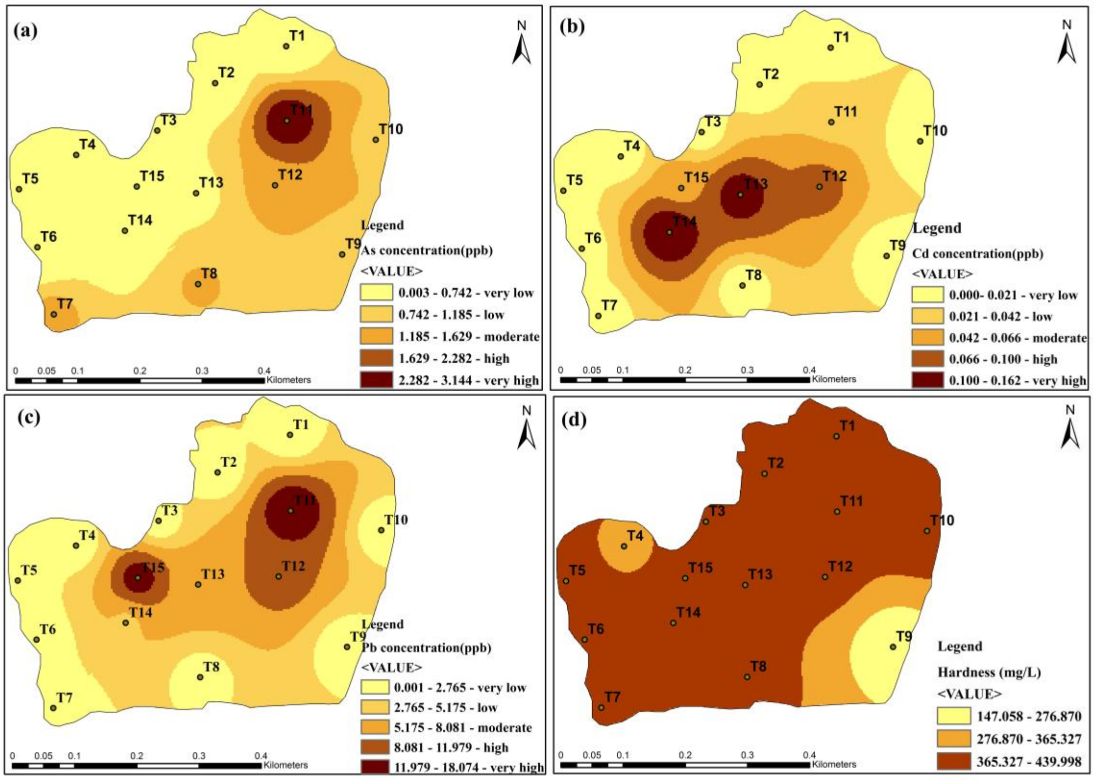

Figure 3. *Spatial distribution of (a) Arsenic, (b) Cadmium, (c) Lead, and (d) Water Hardness in Tissawewa reservoir, Sri Lanka.*

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samples collected from shallow water columns. In contrast, the highest concentrations were found in the middle part of the reservoir.

Cd content of the Tissawewa reservoir ranged from 0.00001 μg/L to 0.16246 μg/L. 'Moderate', 'High', and 'Very high' Cd concentrations were distributed throughout the Tissawewa reservoir compared to the 'Low' and 'Very high' concentrations, while 'Low' and 'Very low' As concentrations distributed more than half of the reservoir where the 'Moderate', 'High', and 'Very high' Cd concentrations were distributed in a small part of the reservoir (Figure 3(a) and 3(b)).

Pb concentrations of Tissawewa reservoir were ranged from 0.0016 μg/L to 18.0745 μg/L. Deepwater columns of the reservoir showed higher Pb concentrations compared to the shallow water columns. 'Very high' Pb level ranged from 11.9793 μg/L to 18.0745 μg/L in analyzed water samples, which were exceeding the maximum permissible level for drinking water (Table 3).

According to the results, almost all the total water hardness values in the Tissawewa reservoir exceeded the maximum permissible levels. The highest and the lowest hardness values for Tissawewa were 440 mg/L and 147 mg/L, respectively. Indications for the water hardness were shown in Figure 03 (d). It shows that all the sampling locations were ranged from 385 mg/L - 440 mg/L except for two sampling locations in the Tissawewa reservoir located in the shallow water columns.

All living beings use water to carry out various life activities, and it is needed to process the integrity of biological ecosystems and the quality of the environment. Water pollution can be defined as the addition of various substances to the water that brings harmful effects to the living organisms and destroys ecological systems' processes. Reservoirs and other water bodies are subjected to different degradation forms due to pollution ascending from the dumping of domestic wastes and industrial effluents, and other anthropogenic activities. Changes in physicochemical parameters and rainfall are another fact which significantly affects the concentrations and the mobility of the heavy metals in a reservoir (Anash et al., 2018).

The higher concentrations of heavy metals in deep water columns are possibly associated with urbanization, industrialization, development activities, agricultural activities, and wastewater discharges (Espinosa et al., 2018). This study's findings confirm the earlier work of Anash et al. (2018), who reported that heavy metals in the bottom layers of the reservoirs are much higher. Due to the sediments that bear heavy metals as carbonates, oxides, and hydroxides are precipitated and settled at the bottom of the reservoirs, elevated levels of heavy metals impact the river's benthic biota. Sediments act as a sink for environmental toxicants such as heavy metals and other pollutants, and they release these toxicants into the water columns. Compared to the concentrations of heavy metals in reservoir water, heavy metal concentrations in suspended particles are higher because when heavy metals released into the water systems, they show a large tendency to bind to suspended matter, which acts as scavengers, and they accumulate in aquatic systems through sedimentation (Anash et al. 2018). Wijesinghe and Manage (2012) described heavy metals such as Pb and Cd are toxic to the biota even at deficient levels, which are non-essential elements and accumulate in human tissues and harmful to human health. Compared to the flowing surface water, heavy metals and other inorganic substances are hold on longer in reservoir waters, which increases the risk for exposure of environmental toxicants to both aquatic animals and human who utilize water and food products from reservoirs due to the concentration and the duration (Wijesinghe et al., 2012).

Environmental toxicants in reservoir waters and sediments are mainly associated with natural processes and human intervention in the biogeochemical cycle of metals (Saleem et al., 2015). Some heavy metals are directly related to fertilizers, pesticides, and other agrochemicals used for agricultural activities (Espinosa et al., 2018). Kalawewa and Tissawewa reservoirs are connected to the Yodha Ela cannel, allowing them to exchange sediments to the reservoirs. Furthermore, soil erosion caused by monsoon rain facilitates the

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transportation of different hazardous chemical substances into the reservoirs, which respond to the concentrations found in this study.

The heavy metal concentrations are shown by the study emphasize the presence of nephrotoxic heavy metals, and it directly shows the problem of environmental pollution. The middle zones of both analyzed reservoirs presented the higher heavy metal contents compared to the shallow water columns according to the IDW tool of ArcMap 10.2.2 software, and higher total hardness values were evidenced throughout both Kalawewa and Tissawewa reservoirs. Therefore, due to the importance of both Kalawewa and Tissawewa reservoirs, it is highly recommended to continually monitor the toxic heavy metals, hardness, and other water quality parameters in the water bodies.

Most of the fertilizers used for agricultural activities are essential for adequate nutrients and successful harvests. Still, long-term and repeated application of chemical fertilizers, nephrotoxic heavy metal-containing pesticides, weedicides, and fungicides can gradually accumulate to potentially harmful levels (Jiao et al., 2012).

Although the causative factors and possible relationship between chronic renal failures and the quality of drinking water are still in debates, water hardness in most of the Sri Lankan reservoirs in the dry zone is significantly higher as compared to the recommended levels emphasizing a relationship with the geographical distribution of chronic renal failures such as Chronic Kidney Disease of unknown etiology (CKDu). Premarathne et al., (2018) have found that the total water hardness levels were higher in Bandagiriya Reservoir (146-180 mg/L), Lunugamwehera Reservoir (128-134 mg/L), Walawe River (112-127 mg/L), as compared to the total water hardness in reference site: Godagama (9-84 mg/L) where no CKDu prevalence. The present study's findings confirm the earlier work of Premarathne et al., (2018), as higher total hardness values were resulted by both Kalawewa (396-1040 mg/L) and Tissawewa (147-440 mg/L) where CKDu prevalence.

According to Dissanayake and Chandrajith (1999), dissolved Ca and Mg carbonates and silicates contain most of the natural water supplies in the dry zone of Sri Lanka, and both geochemical and biochemical influence by these chemical species are making a significant impact on the etiology of kidney disease. The combined and synergistic effect of water hardness and other environmental toxicants is a causative agent for CKDu due to the controlling influence on solubility and precipitation of toxicants such as heavy metals. In addition to chronic renal failures, studies of Rylander et al., (1991); Yang, (1998); Leurs et al., (2010); Knezović et al., (2014) have shown an inverse relationship between drinking water Mg level and heart diseases. According to the studies of Yang et al., (2016), the increase in the ratio of Ca^{2+}/Mg^{2+} in drinking water is contributed to the occurrence of urolithiasis disease. Wickramarathna et al., (2017) observed that the hardness values are as high as 516 mg/L in some groundwater in CKDu affected areas in Sri Lanka, and it is indicating the 'very hard water' (>180). Therefore, these studies revealed a close relationship between chronic renal failures and other non-communicable diseases with the synergistic effect of high water hardness and high heavy metal contents in drinking and irrigation water.

The present study shows that water in both Kalawewa and Tissawewa reservoirs is contaminated with Cd, As, and Pb. In addition to that, the water hardness levels are higher, indicating the 'very hard water'. Therefore, these waters are not suitable for human consumption due to the extensive use and long term exposure to environmental toxicants that may have caused chronic failures such as CKDu. They may cause extreme contamination even for the fishes in the reservoirs. These findings emphasize the need for better catchment management approaches and remediation of urban impacts on both reservoirs' water quality. Reservoir management is an essential tool to improve water quality, and sediment removal can reduce the release of accumulated metals and inorganic substances in the water column. Furthermore, it is obligatory to perform continuous monitoring for heavy metal, Ca, and Mg contamination in reservoirs to reduce the potential health risks. It

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is necessary to take responsibility and actions to minimize environmental harm, protect watersheds, and preserve water quality and the environment for current and future generations.

Conclusions

This study was designed to determine the spatial distribution of selected nephrotoxic heavy metals and total water hardness in Kalawewa and Tissawewa, two major reservoirs in Sri Lanka. Total water hardness values were higher in analyzed water samples in both reservoirs, and these concentrations exceeded the maximum permissible levels of SLS standards for drinking water. The water samples in both reservoirs were contaminated with Cd, Pb, and As in relatively low concentrations. These concentrations complied with the maximum permissible levels of SLS, WHO standards for drinking water, and irrigation water standards. The possible sources of this type of nephrotoxic heavy metal pollution may be related to the excess pesticides and fertilizers application in farming activities within the reservoirs' catchment area. The continuous application of anthropogenic waste may increase the pollution levels of reservoir water. Although the analyzed nephrotoxic heavy metals and total water hardness values were detected at varying concentrations, the spatial distribution was higher in centers of both Kalawewa and Tissawewa reservoirs compared to the shallow water columns. Spatial distribution patterns of nephrotoxic heavy metals and total water hardness may be due to the sediments that bearing heavy metals as carbonates, oxides, and hydroxides, which precipitated and settled at the bottom of the reservoirs. Hence, bottom sediments act as a sink for environmental toxicants such as heavy metals and other pollutants, and they release these toxicants into the water columns. Thus, the study's findings provide the critical background information needed for proper management of reservoirs, especially in dry zone areas.

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