WATER QUALITY CHALLENGES TO ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS IN SRI LANKA

G. Joseph, M. Shamsudduha*, A. Bahuguna, J. Lee, S. Wijesundera, S. Nair, Y.R. Hoo, Q. Wang

Abstract: In Sri Lanka, nearly 93% of all water supply comes from improved sources. However, concerns over degrading water-quality remain a major challenge for the nation, hindering its commitment to achieving the UN Sustainable Development Goals by 2030. This study looks at the water quality in Sri Lanka using information on surface water and groundwater resources. Groundwater quality data for 688 wells were collated from the National Water Supply and Drainage Board (NWSDB). A systematic literature review was conducted to analyze surface water quality. The analyses and literature review reveal the state of water quality across the island. Physical and chemical parameters were examined from the NWSDB database. A groundwater-quality risk index map was developed using multiple parameters at the district level. Results show that water quality is the poorest in Hambantota district located in the dry climate zone. Other districts (e.g., Anuradhapura, Kurunegala, Vavuniya) are found with poor water-quality indices. Surface water quality in some major river basins (e.g., Kelani) is polluted with high levels of chemicals derived from industrial waste and agrochemicals. Regular water quality monitoring is crucial for the long-term sustainability of public water supplies in Sri Lanka.

Keywords: Public water supply, Groundwater, Surface water, Water-quality risk.

1. Introduction

Good quality water for drinking and domestic use is fundamental to human health and wellbeing (UNEP, 2016). In other words, access to good-quality water, together with an adequate quantity of fresh water, is necessary for achieving the United Nation's Sustainable Development Goals (SDGs) for good human health, water and food security in the world.

A recent report (Damania et al., 2019) on global water quality reveals that rich and poor countries alike endure high levels of water pollution.

***Dr. G. Joseph**, Senior Economist, The World Bank, Washington DC, USA*
****Correspondence to Dr. M. Shamsudduha***
Associate Professor, Institute for Risk and Disaster Reduction, University College London, London, UK
Email: m.shamsudduha@ucl.ac.uk
ORCID: https://orcid.org/0000-0002-9708-7223
***A. Bahuguna,** Water Supply and Sanitation Specialist, The World Bank, Washington DC, USA*
***J. Lee**, Research Associate, University of Sussex, Brighton, UK*
***S. Wijesundera**, The World Bank, Washington DC, USA*
***S. Nair,** The World Bank, Washington DC, USA*
***Y.R. Hoo,** The World Bank, Washington DC, USA*
***Q. Wang,** The World Bank, Washington DC, USA*

Sri Lanka, home to nearly 22 million people in an area of 65,610 km^2 (www.statistics.gov.lk), is in South Asia (Figure 1). The per-capita total internally renewable freshwater resource is ~2,487 m^3/year – more than twice (1,131 m^3) per-capita freshwater in South Asia (FAO, 2016).

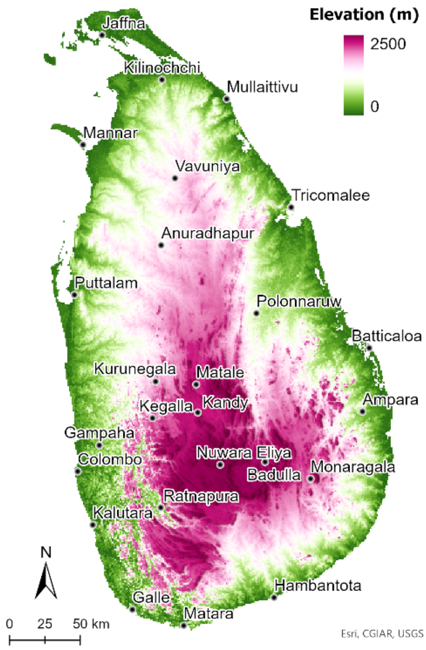

Figure 1 – Surface elevation map of Sri Lanka and the location of major towns in 25 districts.

Over the years, Sri Lanka has come a long way in providing safe drinking water to its population. For example, the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene reports (JMP, 2021) that 76.4% of all water supplies in Sri Lanka in 2000 were of improved quality, of which, piped water-supply was 22%, non-piped was 54% and nearly 10% of all water supplies came from surface water sources. By 2016, Sri Lanka's 85.4% national water supplies came from improved sources of which 36% was piped water supply, 50% was non-piped water supply and about 6% water supply was still sourced from surface water (JMP, 2021).

In Sri Lanka, both surface water and groundwater resources are widely used for domestic, commercial, and industrial purposes, and small-scale irrigation (FAO, 2011; Indika et al., 2022). Two large cities in the country, namely the Capital City of Colombo and Kandy rely on surface water resources for public water supplies (Herath, 2014). Other relatively large urban centers also depend for their water supplies on groundwater (Villholth & Rajasooriyar, 2010). Approximately, one third of the 300 urban and rural water-supply schemes across Sri Lanka is based on supplies from groundwater sources (Panabokke & Perera, 2005).

Water quantity challenges receive a great deal of attention from the development community around the world (Ravenscroft & Lytton, 2022), particularly in the Global South; however, water quality impacts are equally, or even more, critical as poor water-quality impacts on public health. Water quality in surface and groundwater-fed water supplies varies regionally and locally in Sri Lanka. It is reported Mahagamage and Manage (2014) that most observed sites in the Kelani River basin, which hosts more than a quarter of the national population and provides about 80% of drinking water to the Colombo area, has a poor water quality index. Their results further showed that the water quality parameters are above the permissible levels recommended by the WHO and the Sri Lankan standards for drinking water. There is evidence of increasing water-borne diseases and chronic health issues in recent times linked to poor drinking water quality and supply systems in Sri Lanka (Premanath, 2021). Because of the lack of continuous monitoring data, it is difficult to assess the trend in water-quality parameters in public water bodies which include surface water and groundwater sources.

This study provides an overview of water-quality issues at the national scale in Sri Lanka by characterizing the geographic variability in surface water and groundwater resources. This is achieved through an original analysis of groundwater quality data collated from the National Water Supply and Drainage Board (NWSDB), and a systematic literature review of surface and groundwater quality across Sri Lanka. Multi-hazard risks of groundwater quality are mapped using available datasets and population exposure is estimated at the district level. Finally, this paper discusses the challenges to achieving the Sustainable Development Goals and potential pathways of climate change impacts on water quality and future water supplies in Sri Lanka.

2. Datasets and Methods

There is a vast amount of water-quality data scattered over several organizations in Sri Lanka that operate within the water sector (Premanath, 2021). These agencies include the National Water Supply and Drainage Board (NWSDB), Water Resources Board (WRB), Central Environmental Authority (CEA) and many others. However, no national-level monitoring network and a unified national database exists for continuous monitoring of surface water and groundwater quality in the country.

2.1 Groundwater quality datasets

This study has collated groundwater quality dataset from the NWSDB monitoring database at the national scale in Sri Lanka. A total of 770 data points were collated on various groundwater physical and chemical parameters from the NWSDB. However, only 689 data points have location coordinates and one with no significant information. So, in this final analysis 688 georeferenced data points (Figure 2) are used that cover entire Sri Lanka.

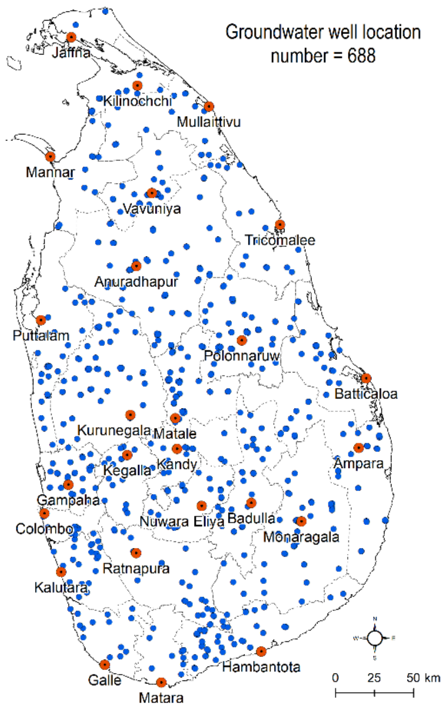

Figure 2 – Location map of the 688 groundwater quality data points.

These wells are water-supply wells that were installed by NWSDB over a long period of time. In it found in the same NWSDB database that the construction year of these 688 wells ranges from 1979 to 2020 and most of these wells were installed in the mid-1980s. For example, 43, 56, 50 water wells were installed in 1985, 1986, 1987 respectively.

Statistical analyses on the 688 water quality data were performed in R programming language (R Core Team, 2020). Geospatial maps were produced by interpolating point data of groundwater quality variables in ArcGIS (version 10.8) software.

2.2 Groundwater risk mapping

Geospatial maps of groundwater multi-hazard risk indices are useful tools for visualization of composite water-quality related hazards and spatial variability (Shamsudduha et al., 2020). Groundwater multi-hazard risk mapping is conducted using well data collated from the National Water Supply and Drainage Board. The number of groundwater samples selected for each district varies. A method was developed (eq. 1) in this study to characterize groundwater quality hazard risks using a total of 688 data points from 25 districts. Concentrations of ten groundwater quality parameters: Chloride (Cl), Alkalinity, Nitrate (NO_3), Nitrite (NO_2), Fluoride (F), Phosphate (PO_4), TDS, Hardness, Iron (Fe), and Sulphate (SO_4) using the following formula:

$$GW_{hazard\ risk} = \frac{1}{n}\left\{\sum_{par=n}^{1} 100\% \times (No\ of\ GW_{par} > WHO_{std})\right\} \quad .... (1)$$

$GW_{hazard\ risk}$ is groundwater multi-hazard risk index based on concentrations of water quality parameters $GW_{par\ (n=10)}$ exceeding the WHO standards (Table 1) within each of the 25 districts in Sri Lanka. Exploratory analyses revealed that there are missing data for a number of groundwater quality parameters. For the estimation of $GW_{hazard\ risk}$ all missing data gaps are imputed or infilled using a non-parametric missing value imputation method using Random Forest machine learning algorithm from the *missForest* package in R environment (Stekhoven & Buehlmann, 2012).

2.3 Surface water quality analysis

There is limited availability of data on the continuous monitoring of surface water quality in Sri Lanka. A systematic literature search was conducted using the Web of Science and Scopus databases on 23 March 2022. Through the screening process, a total of 86 papers out of 215 from the search were finally included in the review and synthesis.

Surface water-quality dataset for Sri Lanka was derived from a global-scale analysis of water quality (1992 to 2010) conducted by the World Bank (Damania et al., 2019). The report explored global water quality and its changes for ~20 years focusing on five major parameters that were tracked by the UN Sustainable Development Goals (SDGs) and considered critical for surface water quality. These parameters include nutrients (Nitrate-Nitrite) (NO_x-N), Total Phosphorous (TP), water salinity as Electrical Conductivity (EC), Biological Oxygen Demand (BOD), and Dissolved Oxygen (DO).

Table 1 – Groundwater quality parameters and their descriptive statistics at the national scale in Sri Lanka (data source: National Water Supply and Drainage Board, NWSDB).

Variable	WHO Standard	Sri Lanka Standard†	No of data point	Mean	Medi -an	Std Dev	Mini-mum	Maxi-mum
Well depth	N/A	N/A	688	43.6	40.0	16.0	4.0	105
Yield	N/A	N/A	669	136.7	35.0	334.0	0.3	3200
GWL depth	N/A	N/A	509	13.5	11.0	8.8	1.0	61
pH	6.5-8.5	6.5-9.0	675	7.3	7.4	0.7	4.2	9
[1]Chloride	250	200-1200	598	191.3	50.0	487.5	1.0	4930
[1]Alkalinity	400‡	400	613	208.8	181.0	142.4	8.0	960
[1]Nitrate	10	10	316	2.6	0.7	5.6	0.0	48
[1]Nitrite	1.0*	0.01	208	0.4	0.01	1.8	<0.01	21
[1]Fluoride	1.5	0.6–1.5	613	0.9	0.6	0.9	0.01	8
[1]Phosphate	0.1	2.0	199	0.7	0.4	1.0	<0.01	9
[1]TDS	600††	500–2000	348	584.7	324.5	873.5	15.00	8322
[1]Hardness	500	250–600	659	266.3	180.0	368.4	10.00	3880
[1]Iron	0.3	1.0	620	2.7	0.6	7.4	0.01	120
[1]Sulphate	400	200-400	437	42.3	19.0	85.4	1.00	776

†Standard values are taken from the Sri Lanka Standards for potable water (SLS 614, 2013) with highest desirable and maximum permissible limits for certain parameters.
††Any value between 300 and 600 mg/liter is considered to be good.
‡ No WHO standard for Alkalinity is found; this standard is used by some states in the USA.
*Nitrite standard is taken from the U.S. Environmental Protection Agency (EPA)
[1]Variables used in the calculation of groundwater multi-parameter hazard risk index.

3. Results

3.1 Groundwater quality mapping

Analysis of 688 groundwater quality data points reveals substantial variability in water chemistry across Sri Lanka. Descriptive statistics were calculated for districts, aquifer types and climate zones. For example, groundwater salinity as indicated by the Total Dissolved Solids (TDS) is the highest in Batticaloa district (mean value of 1564 mg/liter) compared to the national average value of 536 mg/liter. The district with the least mean TDS value (115 mg/liter) is Kalutara. In terms of aquifer types, shallow alluvial aquifer has the highest (1034 mg/liter) mean concentrations of TDS, whereas the lowest mean TDS value (214 mg/liter) is found in the Laterite (Cabook) aquifer. TDS values range from 875, 436, to 179 mg/liter in the dry, intermediate, and wet climate zones respectively in Sri Lanka.

Figure 3 shows percentage of various groundwater quality variables exceeding the WHO drinking water standards in 25 districts in Sri Lanka.

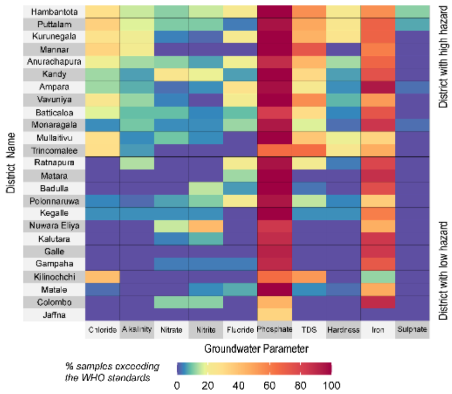

Figure 3 – Time-series plots showing changes in surface

3.2 Surface water quality statistics

Figure 4 shows country-wide aggregated monthly time-series data of five surface water parameters (NOx-N, TP, EC, BOD and DO). Plots show temporal variability in these parameters between 1992 and 2010 with an indication of overall rising trends in almost all these variables, especially since 2005.

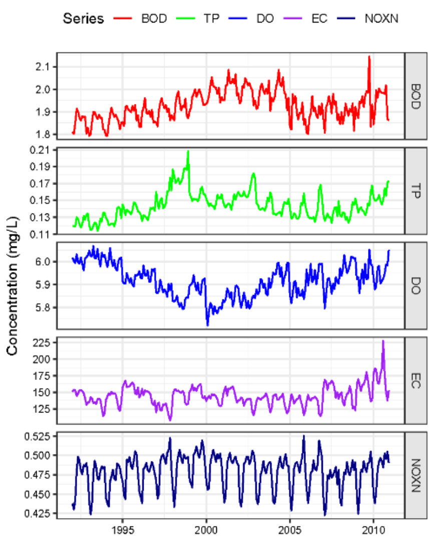

Figure 4 – Time-series plots showing changes in surface water quality.

3.2 Groundwater quality risk map

Figure 5 shows groundwater multi-parameter hazard risks at district levels in Sri Lanka. The Map shows that the groundwater quality is poorest in Hambantota district, and best in Jaffna based on ten groundwater quality variables shown in Table 1. An estimated 4.7 million (22% of the total population) people are exposed to poor groundwater quality risks to adverse health outcomes in Sri Lanka.

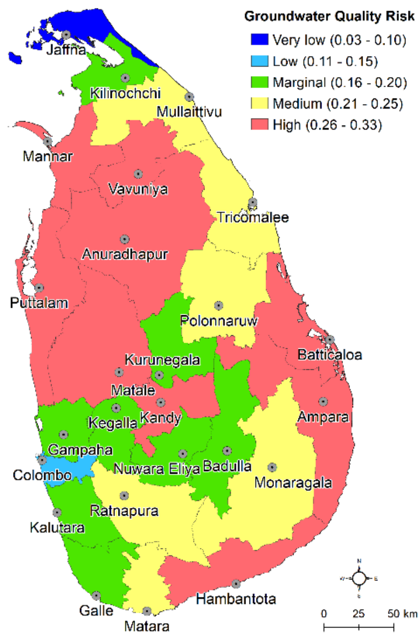

Figure 5 – Map shows groundwater quality risk index in 25 districts.

4. Discussion

4.1 Water quality in Sri Lanka

Analysis of surface water and groundwater quality at the national scale in Sri Lanka reveals a high degree of spatial variability due to climate variability, complex geology and water-rock interactions, and land-use. High salinity, fluoride and phosphate are among the most health hazards in groundwater-fed drinking water supplies in the country. The literature review of surface water-quality information reveals pollution in several river basins (Kumar, Chaminda, et al., 2020). Surface water pollution in Sri Lanka has been caused by natural as well as anthropogenic activities such as irrigation, manufacturing, and disposal of municipal and agricultural wastes and pollutants. Large quantity of industrial and agricultural chemicals has been released to the river network, especially in the densely populated Kelani River basin where many industries are located (Kumar, Sulfikar, et al., 2020). The increased amount of waste and pollutants from these sources has been discharged directly into rivers, and, as a result, surface water becomes contaminated. The quality of surface water is at a threat from anthropogenic activities all over the world, and Sri Lanka is not an exception. Both surface and groundwater quality have been deteriorated intensely during the last few decades due to the rapid industrialization and urbanization in Sri Lanka.

4.2 Water quality challenges and sustainable development goals

This study has highlighted the lack of continuous monitoring of surface and groundwater quality data at the national scale in Sri Lanka. Without time-series data on surface and groundwater quality, it would be challenging to attribute whether the water quality deterioration in Sri Lanka is due to climate change or anthropogenic activities such as land-use. Establishing water-quality monitoring systems at strategic locations will help the country achieve the SDGs, particularly SDG 3 (good health and well-being) and 6 (clean water and sanitation for all).

5. Conclusions

This study concludes that, in order to ensure public water supply and good human health, Sri Lanka needs to invest in establishing water-quality monitoring infrastructure. This will also ensure that the nation can achieve the UN Sustainable Development Goals (SDGs 3 and 6). Findings from this review analysis are expected help increase public awareness and policy take-up.

Acknowledgements

Authors wish to acknowledge Sri Lanka’s National Water Supply and Drainage Board (NWSDB) for the groundwater quality dataset.

References

Damania, R., Desbureaux, S., Rodella, A.-S., Russ, J., & Zaveri, E. (2019). *Quality Unknown: The Invisible Water Crisis*.

FAO. (2011). *AQUASTAT Country Profile – Sri Lanka*.

FAO. (2016). *AQUASTAT website*. Food and Agriculture Organization (FAO). Retrieved 26 May 2016 from https://www.fao.org/aquastat/en/

Herath, G. (2014). *Water quality management in Sri Lanka: current situation and issues*. University of Peradeniya.

Indika, S., Wei, Y., Cooray, T., Ritigala, T., Jinadasa, K. B. S. N., Weragoda, S. K., &

Weerasooriya, R. (2022). Groundwater-based drinking water supply in Sri Lanka: status and perspectives. *Water, 14*, 1428.

JMP. (2021). *Joint Monitoring Programme for Water Supply, Sanitation and Hygiene: Estimates on the use of water, sanitation and hygiene in Sri Lanka, WHO and UNICEF*.

Kumar, M., Chaminda, G. G. T., & Honda, R. (2020). Seasonality impels the antibiotic resistance in Kelani River of the emerging economy of Sri Lanka. *npj Clean Water*, *3*(12). https://doi.org/10.1038/s41545-020-0058-6

Kumar, M., Sulfikar, Chaminda, T., Patel, A. K., Sewwandi, H., Mazumder, P., Joshi, M., & Honda, R. (2020). Prevalence of antibiotic resistance in the tropical rivers of Sri Lanka and India. *Environmental Research Letters*, *188*, 109765. https://doi.org/10.1016/j.envres.2020.109765

Mahagamage, M. G. Y. L., & Manage, P. M. (2014). Water Quality Index (CCME-WQI) Based Assessment Study of Water Quality in Kelani River Basin, Sri Lanka. ENRIC2014: The 1st Environment and Natural Resources International Conference, Bangkok, Thailand.

Panabokke, C. R., & Perera, A. P. G. R. L. (2005). *Groundwater Resources of Sri Lanka*.

Premanath, L. (2021). *Sri Lanka water quality study*.

R Core Team. (2020). *R: A language and environment for statistical computing (version 4.0.3)*. In R: A language and environment for statistical computing (version 4.0.3). R Foundation for Statistical Computing, Vienna, Austria.

Ravenscroft, P., & Lytton, L. (2022). *Seeing the Invisible: A Strategic Report on Groundwater Quality*.

Shamsudduha, M., Joseph, G., Haque, S. S., Khan, M. R., Zahid, A., & Ahmed, K. M. U. (2020). Multi-hazard Groundwater Risks to Water Supply from Shallow Depths: Challenges to Achieving the Sustainable Development Goals in Bangladesh. *Exposure and Health*, *12*, 657-670. https://doi.org/10.1007/s12403-019-00325-9

SLS 614. (2013). *Sri Lankan Standards for potable water*.

Stekhoven, D. J., & Buehlmann, P. (2012). MissForest - nonparametric missing value imputation for mixed-type data. *Bioinformatics*, *28*(1), 112-118. https://doi.org/10.1093/bioinformatics/btr597

UNEP. (2016). *A snapshot of the world's water quality: towards a global assessment*.

Villholth, K. G., & Rajasooriyar, L. D. (2010). Groundwater resources and management challenges in Sri Lanka–an overview. *Water Resour. Manage.*, *24*, 1489–1513.