Impact of Leachate on Bore Well along the Perimeter of Papua New Guinea University of Technology Due to Open Dump site

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Abstract: Water is a valuable resource and is vulnerable to contamination. Waterborne diseases are rampant in Papua New Guinea (PNG). The samples are extracted along the perimeter of PNG University of Technology to investigate the impact of leachates on the bore wells due to the dumping of municipal solid waste (MSW) or waste materials along the boundary. In this study, the major contaminants determined include microbiological, physico-chemical parameters of ground and surface water, and heavy metal (Cd, Pb, and Hg) contaminants. The results from water analyses significantly show a high concentration of total coliforms and heavy metal contamination when compared to the World Health Organization's (WHO) guidelines for drinking water quality. The results indicate that bore wells near the dumping sites contained microbial and heavy metal contaminants. The positive total coliform and detection of cadmium (Cd), lead (Pb), and mercury (Hg) in bore wells nearer the dumping area are indications of contaminants leaching and impacting the bore wells.

Keywords: Municipal solid Waste (MSW), Open Dump Site (ODS), Leachate, Heavy Metals contaminants, microbiological contaminants.

1. Introduction

Water is a fundamental component for sustaining life, yet it is increasingly compromised by human activities associated with industrialization, urbanization, and agricultural practices. The improper disposal of waste, particularly through the open dumping of municipal solid waste (MSW), poses significant risks to groundwater quality [1, 2]. Landfills and open dump sites (ODS) are recognized as critical threats to groundwater resources [3, 4]. ODS are characterized as locations where solid waste is disposed of without adequate environmental safeguards, making them vulnerable to open burning and exposure to environmental elements, vectors, and scavengers [5]. Current investigations are focusing on the practice of open dumping in proximity to bore wells. To elucidate the relationship between bore well contamination and waste disposal, various microbial and physicochemical parameters, including heavy metals, have been analyzed in both surface water and groundwater samples. Research indicates that contaminants infiltrate bore wells via the gravitational percolation of leachate, which reaches the water table. Studies have demonstrated that the disposal of municipal solid waste (MSW) and plastics in nearby areas results in elevated levels of dissolved ions and heavy metals [1, 6].

2. Material and Method

2.1 Study Area

Lae City is the capital of Morobe Province and the second-largest city in PNG with the largest cargo port. It is the industrial hub and home of UNITECH. Lae City is surrounded between the larger Indo-Australian Plates and the Pacific Plates on the South Bismarck Plate and lies between 6.7155°S and 146.9999° E. It is characterized by a tropical rainforest climate with an average precipitation of 45000 millimetres of rainfall annually.

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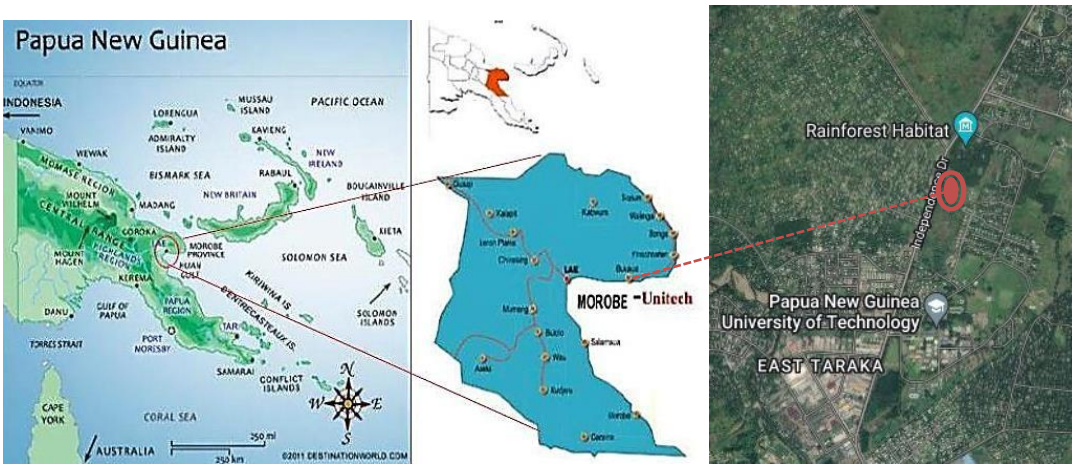


Fig 1: Map of Study Area (Source: Google Map)

The generation of municipal solid waste (MSW) in Lae City is dumped at the oldest landfill at the Second Seventh dump site, which is northeast of UNITECH and lies between 6.6598°S and 147.0123°E. The current practice of open dumping along the boundary of UNITECH is under investigation. This open dump site shown in Figure 2 is close to the bore wells where water is extracted, treated, and distributed by Water PNG Limited throughout Lae City and surrounding communities for domestic and commercial purposes.

A survey was conducted in the study area on Bore Wells along the boundary of the UNITECH dump site during April and June 2022. The methodology for the selection of test parameters was based on the sources of contaminants and the availability of analytical techniques.

The materials and plastics in the close vicinity of the UNITECH boundary are shown in Figure 2, and a map showing the dump site of the current study area is shown in Figure 3.

Fig 2: Types of Solid Waste Dumped at the Landfill

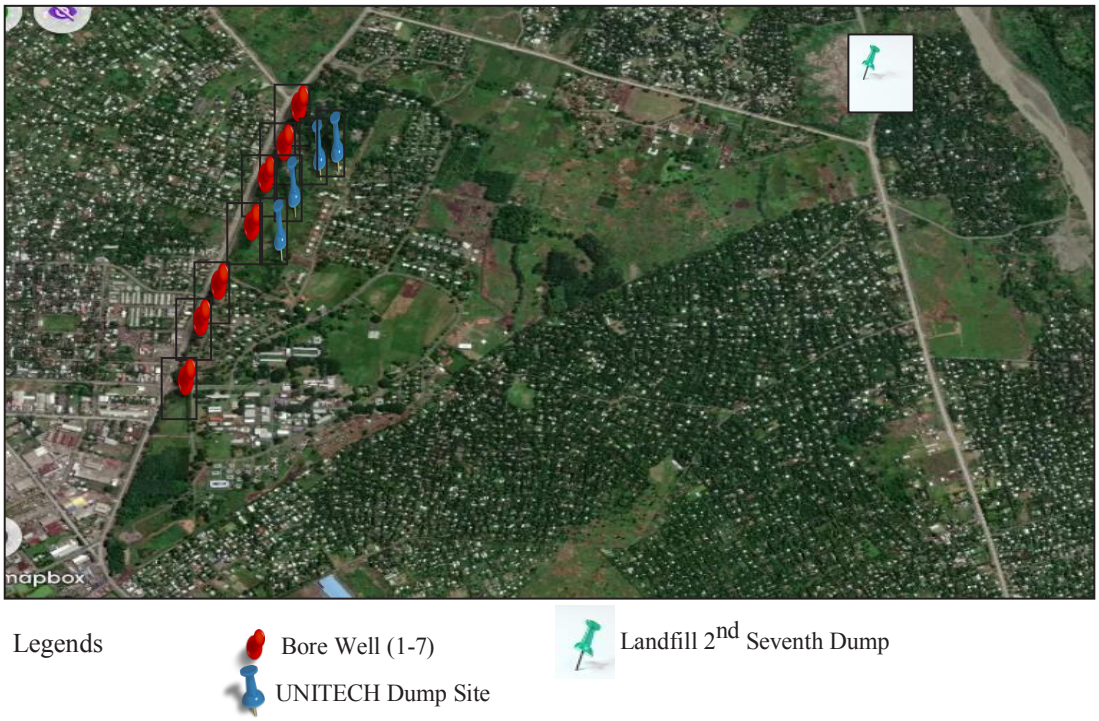


Fig 3: A Google Earth Map Showing the UNITECH Perimeter, The Dump Site, and the Bore Wells

2.2 Investigation Design

The biological, physicochemical, and heavy metal concentrations of surface waters and groundwater along the study zone were assessed to test the hypotheses that the dumping of municipal solid waste (MSW) has been affecting groundwater quality.

2.3 Sampling Plan

Water samples from both surface and bore sources (groundwater) were obtained from seven distinct locations to evaluate the extent of pollution caused by the disposal of municipal solid waste (MSW), as well as plastic and electronic waste near the bore wells. The sampling was conducted around the waste dumping site and the bore wells, following the perimeter boundary outlined in Table 1. It is important to note that samples from BW1, BW2, BW3, and BW5 were not collected due to the malfunctioning of the pump during the sampling process.

Table 1: Locations of Sampling

Description	**Sample ID**	**Longitude**	**Latitude**
Surface water 1	SW1	146° 59' 41.0676" E	6° 39' 47.7576" S
Surface water 2	SW2	146° 59' 36.6756" E	6° 39' 51.9732" S
Bore well 1	BW1	146° 59' 26.8152" E	6° 40' 21.1764" S
Bore well 2	BW2	146° 59' 28.3164" E	6° 40' 12.252" S
Bore well 3	BW3	146° 59' 31.0308" E	6° 40' 8.3676" S
Bore well 4	BW4	146° 59' 33.5364" E	6° 40' 1.3476" S

Bore well 5	BW5	146° 59' 35.5308" E	6° 39' 55.746" S
Bore well 6	BW6	146° 59' 37.3056" E	6° 39' 50.0724" S
Bore well 7	BW7	146° 59' 37.3056" E	6° 39' 43.4592" S
Water Before Treatment	WBT	146° 59' 23.2872" E	6° 40' 8.8716" S
Water After Treatment	WAT	146° 59' 18.8844" E	6° 40' 7.5648" S

2.4 Analytical Technique

All microbiological samples were collected in sterilized bottles that were aseptically kept chilled, taken to the laboratory without delay, and analyzed using the membrane filter (MF) technique to test for total coliforms.

Physico-chemical parameters such as pH, Total Dissolved Solids (TDS), Cadmium (Cd), Lead (Pb), and Mercury (Hg) were analyzed according to the Standard Method of Examination of Water and Wastewater [7].

Heavy metals samples were field spiked with 10% nitric acid to preserve the analyte of interest, filtered using a 0.45um filter, and analyzed using Inductive Couple Plasma-Mass Spectroscopy (ICP-MS) at the 7900 Agilent Mass Hunter. Instrument calibration was done using 0. 0, 0.2, 0.5, and 1.0 mg/L calibration solutions prepared by diluting a mixed standard solution spiked with 1% nitric acid.

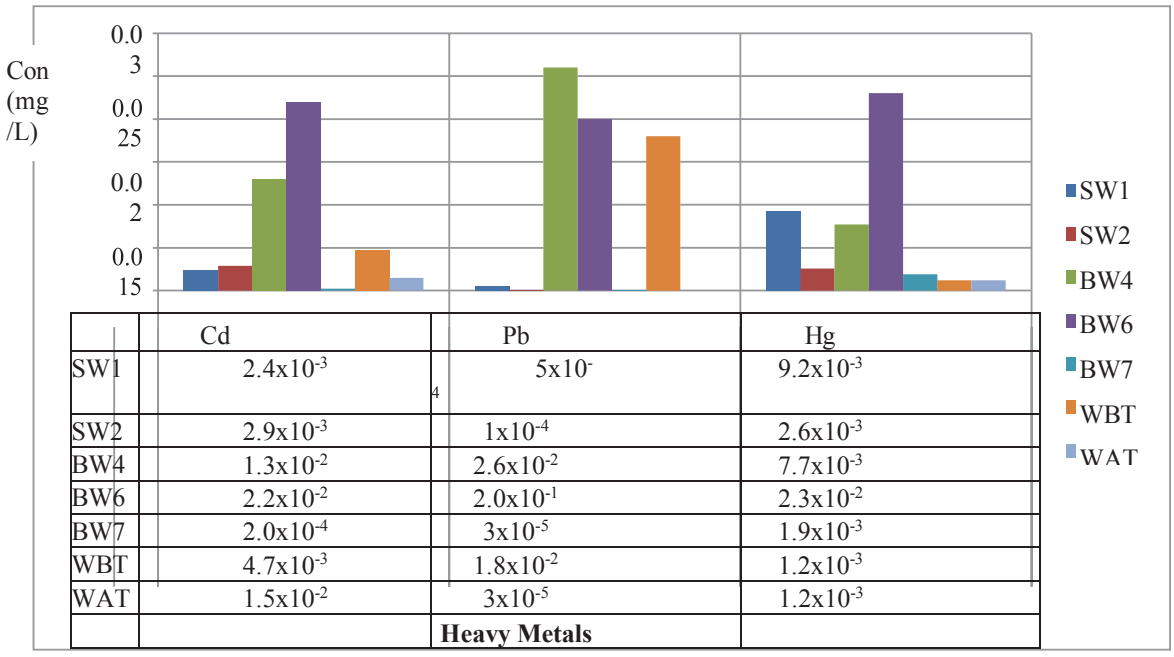
3. Results and Discussion

The bore well located within the study area serves primarily domestic and commercial functions. Consequently, it is crucial to assess the contamination levels of bore wells situated in proximity to waste disposal sites. Table 2 illustrates the analytical findings regarding the quality parameters of surface and groundwater in accordance with World Health Organization standards (Organization 2022). The current investigation reveals that the microbial contamination of total coliforms varies from 0 colony-forming units (CFU) per 100 mL to 14,600 CFU per 100 mL, which exceeds the acceptable limits set by WHO for drinking water. The highest concentrations of coliforms were recorded in surface water samples, specifically SW1 at 6800 CFU/100 mL and SW2 at 14,600 CFU/100 mL. The bore wells BW4 and BW6, which are near SW1 and SW2, respectively, exhibited coliform counts of 120 CFU/100 mL and 500 CFU/100 mL, demonstrating a correlation with the surface water results. In contrast, bore wells located further from the dumping sites, such as BW7, WBT, and WAT, showed no detectable coliforms. The presence of coliforms in BW4 and BW6 suggests contamination of the bore wells adjacent to the dumping sites, indicating significant microbial leaching in these areas. The average standard deviation recorded was 3145.71 ± 5633.17 CFU/100 mL. The lowest pH and total dissolved solids (TDS) measured were 6.8 and 110 mg/L in the surface and bore water samples, respectively. The detection of coliforms points to the presence of organic pollutants, while the identification of heavy metals such as cadmium (Cd), lead (Pb), and mercury (Hg) in samples BW4, BW6, and WBT indicates heavy metal contamination. The open dump site is known to receive fluorescent lamps, batteries, and electronic waste (Figure 2), which are likely sources of heavy metal pollution. The test results clearly demonstrate that heavy metals leach and infiltrate groundwater in the vicinity of the dumping sites. The average standard deviations for cadmium (Cd), lead (Pb), and mercury (Hg) were found to be 0.0066 ± 0.0079, 0.0092 ± 0.012, and 0.0066 ± 0.0071, respectively

Table 2: Bore Well and Surface Water Average Standard Deviations

Parameters	**Sampling Sites**									
	SW1	SW2	BW4	BW6	BW7	WBT	WAT	Average	SD	Permissible Limit WHO
Coliform Total (CFU/100mL)	6800	14600	120	500	0	0	0	3146	*5633*	0
pH Values	6.8	7	7.3	7.5	7.4	7.3	7.4	7.3	*0.2*	7-8.5
TDS (mg/L)	220	110	120	125	163	185	182	158	*40.8*	<500
Cd (mg/L)	0.0024	0.0029	0.0130	0.0220	0.0002	0.0047	0.0015	0.0066	*0.008*	0.003
Pb (mg/L)	0.0005	0.0001	0.026	0.020	0.00003	0.018	0.00003	0.009	*0.01*	0.01
Hg (mg/L)	0.009	0.003	0.008	0.023	0.002	0.002	0.002	0.007	*0.001*	0.006

The WHO's allowable limits for cadmium (Cd), lead (Pb), and mercury (Hg) were exceeded, respectively, by 0.003, 0.01, and 0.006 mg/L. Cadmium (Cd), lead (Pb), and mercury (Hg) were found in samples BW4, BW6, and WBT, while mercury (Hg) was found in samples SW1, BW4, and BW6.
Figure 4 shows a visual representation of the concentration of heavy metals.



	Cd	Pb	Hg
SW1	$2.4x10^{-3}$	$5x10^{-4}$	$9.2x10^{-3}$
SW2	$2.9x10^{-3}$	$1x10^{-4}$	$2.6x10^{-3}$
BW4	$1.3x10^{-2}$	$2.6x10^{-2}$	$7.7x10^{-3}$
BW6	$2.2x10^{-2}$	$2.0x10^{-1}$	$2.3x10^{-2}$
BW7	$2.0x10^{-4}$	$3x10^{-5}$	$1.9x10^{-3}$
WBT	$4.7x10^{-3}$	$1.8x10^{-2}$	$1.2x10^{-3}$
WAT	$1.5x10^{-2}$	$3x10^{-5}$	$1.2x10^{-3}$

Figure 4: Concentration of Heavy Metals at Specific Sampling Locations

4. Conclusion

To conclude, the analysis reveals that total coliform bacteria and heavy metals, specifically cadmium (Cd), lead (Pb), and mercury (Hg), are leaching through the soil and contaminating the bore well, as evidenced by the water sample testing. Total coliform encompasses bacteria typically found in soil, surface water, and the waste of humans or animals. The detection of total coliform bacteria in bore wells BW4 and BW6 suggests the presence of both microbial and chemical contaminants, corroborated by the concentrations of heavy metals (Cd, Pb, and Hg) observed at the study site. Additional analytical sampling and testing of bore wells along the UNITECH boundary will be undertaken, given the presence of microbial and heavy metal contaminants in BW4 and BW6, indicating significant leaching and percolation of pollutants in proximity to the waste disposal areas.

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