REVISED PAPER

ESTIMATING THE TEMPORAL LEACHATE CONTAMINATION POTENTIAL OF YENAGOA CENTRAL WASTE DUMPSITE, USING LEACHATE POLLUTION INDEX, ABANIGI ROAD ETELEBU, NIGERIA

ABSTRACT

Leachates have gradually taken the center stage of environmental discuss in recent times because of their interference with the environment. The potency of any leachate is largely dependent on its concentration which varies with time depending on waste generation patterns, waste stabilization and environmental factors. Leachate pollution index (LPI) provides an overall pollution potential of a landfill site. In this study, the concept of LPI is described in brief and used to estimate the temporal variation of leachate pollution within the dump site. Stepwise procedure to calculate the LPI of a landfill is explained using data from the Yenagoa Central Waste Dump (YCWD), Nigeria. This waste dump have no liners or leachate collection/treatment system, therefore, leachate generated finds its way into the environment. LPI values are a comparative scale used as a hazard identification tool. It is an increasing scale index, where a higher value indicates poor environmental condition based on the Delphi technique. Four samples of leachate were taken at different locations within the dumpsite and mixed for homogeneity. The sampling was done twice, ie, during March and December of 2019. The laboratory data was analyzed for its pollution potential using LPI and comparison made between the two sampling regimes. In the present study, leachate samples were collected and analyzed for 9 significant parameters viz pH, TDS, NO_3, BOD_5, COD, Cu, Zn, Fe and TC. The results obtained showed that the leachate contents were highly contaminated. The March and December analysis showed LPI values of 17.004 and 15.757 respectively, which were beyond the Indian leachate disposal standards for inland surface water (7.378). It was also observed that the leachate concentration during the March analytical period was more toxic than that of the December analytical regime. Therefore, a robust waste management strategy is recommended for the Bayelsa State sanitation Authority.

Keywords: Temporal Variation, Leachate, Leachate Pollution Index (LPI), Delphi Technique, Homogeneity.

1.0 INTRIDUCTION

"Inadequate management of wastes and waste dump sites have recently become a global concern resulting from the complex waste cum leachate produced and released into the environment. Landfills are the most common means of municipal waste disposal in many countries, particularly developing ones worldwide because they offer dumping high quantities of Municipal Solid Waste (MSW) at economical costs in comparison to other disposal methods such as incineration" [1];[2]. "They are capable of releasing large amounts of harmful chemicals to nearby water sources and air through leachates and landfill gas respectively" [3];[4];[5]. "Leachates are characterized by the high concentration of organic matter (biodegradable and non-biodegradable), ammonia nitrogen, heavy metals, and chlorinated organic and inorganic salts" [6]. "The characteristics of leachate are highly variable depending on the waste composition, amount of precipitation, site hydrology, waste compaction, cover design, sampling procedures, and interaction of leachate with the environment, landfill design and operation" [7]. According to [8], the main problem associated with landfills is the formation of leachate and eventual contamination of water resources and soil due to contaminant migration.

"The scale of pollution threat depends on the concentration and toxicity of contaminants in leachate, type and permeability of geologic strata, depth of water table, the direction of groundwater flow, the topography and rainfall intensity" [9]. This leachate is the primary vector of these contaminants from the landfill to the surrounding soil. Landfill leachate usually contains inorganic macro-components, heavy metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, etc. derived from decomposing waste [10]. "Leachate can contaminate surface water if it is not collected and treated, and groundwater where landfills are not provided with impermeable liners prior to its discharge. The overall pollution potential of landfill leachates can be calculated in terms of leachate pollution index (LPI)" [11]. "The identification and quantification of pollutants in landfill leachate remains the major limitation for their successful treatment" [12], "LPI can be used as a means to determine whether a landfill requires immediate attention in terms of introducing remediation measures. This method can be used for comparing leachate pollution potential of various landfill sites in a given geographical area as well as pollution potential of leachate from the same landfill at different times, using the Rand Corporation Delphi Technique" [13]. "It is a single number ranging from 5 to 100, which expresses the overall leachate contamination potential of a landfill based on severe leachate pollution parameters at a given time. It is an increasing scale index, where a higher value indicates a poor environmental condition with the standard LPI value of 7.37" [13].

Therefore, the proper application of LPI will be an important information tool that will enable environmental practitioners, particularly the Bayelsa State Government to take the necessary steps to contain the pollution threat from the dumpsite.

2. STUDY OBJECTIVES

The objectives of the study are;

- To evaluate the characteristics of leachate generated from Yenagoa central waste dumpsite during the March and December 2019 through physico-chemical and biological analysis.
- To use Leachate Pollution Index (LPI) as an evaluation tool to ascertain the quality of leachate produced during the sampling periods.
- To compare the Leachate Pollution Index values of the two sampling regimes so as to know their variability.
- To compare the LPI values analyzed with the standard value of treated leachate ready for disposal.
- To discuss the leachate's potential adverse impacts on nearby environment.

3.0 MATERIALS AND METHOD

3.1 STUDY AREA

The waste dump is located at Abanigi road, Etelebu in Yenagoa Local Government Area of Bayelsa State. It lies at latitude 4^{0}59'28.44276" North and longitude 6019'40.47568" East respectively [14]. The solid waste dump services waste generated from the Yenagoa metropolis, which includes domestic waste, commercial waste, institutional waste, etc. It is in fact the final resting place for more than 95% of all the wastes generated across the growing city. This waste dump is an unlined landfill situated in the Niger Delta wetlands.

3.2 Sample collection and Laboratory Analysis

In this study, leachate samples were collected twice in the year (2019). The first set of samples were collected in March, while the second analysis was in December of 2019.

At every sampling regime, samples for Physico-chemical and microbiological analysis were taken in 50 ml sterile universal containers, and analysis conducted. The samples were carefully collected from the landfill site and in-situ measurement of temperature and pH was done. The leachate accumulating at the base of the waste dumpsite was sampled randomly from four different locations within the waste dump and mixed for homogeneity. The samples were then transferred to the laboratory in an ice cooler and stored in a cold room at 4°C. Prior to analysis, the samples were allowed to return to room temperature and measurements for leachate parameters were carried out. The parameters measured for the landfill are given in Tables 1.0 below.

The leachate samples were analyzed for the relevant Physico-chemical parameters according to internationally accepted procedures and standard methods. The parameters analyzed included pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Total Hardness (TH), Sodium (Na^{+}), Sulphate (SO_4^{2-}), Ammonium (NH^{4+}), Iron (Fe), Zinc (Zn), Cadmium (Cd), and Lead (Pb). The concentrations of heavy metals were determined using atomic absorption spectrophotometer [15]. Microbial enumeration was carried out using serial dilutions on the leachate samples collected.

Table 1.0: Summary of Physico-Chemical Properties of Leachate Samples

Sample ID	Units	WHO GUIDELINES (2011)	MARCH, 2019	DECEMBER, 2019
pH		6.5-8.5	7.7	7.58
Temp.	0C	25	21.7	23.8
EC	µS/cm	1000	12,250	1,247
TDS	mg/l	500	6,125	623
SO^{2-}_4	mg/l	500	160	58
NO_3	mg/l	50	0.4	0.3
PO^{3-}_4	mg/l	5	5	3.2
NH_4	mg/l	NA	0.09	0.068
Alkalinity	mg/l		2,037	860
BOD	mg/l	5	10	12
COD	mg/l	10	366	337
Hardness	mg/l	200	560	400
Pb	mg/l	0.01	<0.001	<0.001
Cu	mg/l	2	0.02	<0.001
Zn	mg/l	3	0.11	0.08
Fe	mg/l	0.3	8.04	4.765

Ca	mg/l	75	4.02	12.107
Mg	mg/l	20	47.18	64.781
K	mg/l	20	1.27	32.758
Na	mg/l	200	513.69	141.584
Cd	mg/l	0.003	<0.001	<0.001
Cr	mg/l	0.05	<0.001	<0.001
Total Plate Count	(cfu/ml)	0	2.80×10^{6}	3.00×10^{7}

N.B: BDL means below instrument detectable limits

3.3 The Concept of LPI

In a bid to compare the leachate pollution potential of a landfill during two analytical periods, an index known as LPI was formulated using Rand Corporation Delphi Technique. The formulation process and complete description on the development of the Leachate Pollution Index, has been discussed elsewhere [16]. The LPI represents the level of leachate contamination potential of a given landfill. It is a single number ranging from 5 to 100 (like a grade) that expresses the overall leachate contamination potential of a landfill based on several leachate pollution parameters at a given time. It is an increasing scale index, where a higher value indicates a poor environmental condition. The LPI can be used to report leachate pollution changes in a particular landfill over time. The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The leachate trend at a given landfill site can facilitate design of leachate treatment facilities for other landfills in the same region. LPI can also be used to compare leachate contamination potential of different landfills in a given location or around the world. The other potential applications of LPI include ranking of landfill sites based on leachate contamination potential, resource allocations for landfill remediation, enforcement of leachate standards, scientific research and public information etc [17].

3.3.1 Variables Selected in this Study

Nine leachate pollutant variables were selected for inclusion in LPI. They are pH, Total Dissolved Solids (TDS), Nitrate (NO_3), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Copper, Zinc, Total Iron and Total Coliform Bacteria.

3.3.2 Calculation of Leachate Pollution Index (LPI)

The data from the laboratory analysis of samples as indicated in Table 1.0 above, was used in the LPI analysis. The 'P' values or sub-index values for all the parameters analyzed were computed from the sub-index curves in Figures 1.0 and 2.0 based on the concentration of the leachate pollutions obtained during the analysis. The 'P' values were obtained by locating the corresponding value on the vertical axis of the curve from the concentration of the leachate pollutant on the horizontal axis where it intersected the sub-index curve. The 'P' values obtained for the parameters analyzed were multiplied with the respective weights assigned to each parameter. The LPI for the dumpsite leachate was calculated using the equation of [18] shown in equation (1) below.

$$\text{LPI} = \sum_{i}^{n} w_i p_i \quad (1)$$

Where;

LPI = Leachate pollution index

w_i = The weight for the ith pollutant variable

p_i = The sub-index value of the ith leachate pollution variable

n = 23

$\sum w_i$ =1.

However, when the data for all the pollutant variables included in LPI is not available, the LPI can be calculated using data set of the available pollutants by equation 2 below;

$$\text{LPI} = \frac{\sum_{i=1}^{m} w_i p_i}{\sum w_i} \quad (2)$$

Where;

LPI = Leachate pollution index

w_i = The weight for the ith pollutant variable

p_i = The sub-index value of the ith leachate pollution variable

m = The number of leachate pollutant parameters for which data is available

4.0 RESULTS AND DISCUSSION

Figures. 2.0 and 3.0 presented the average sub-index curves of pollutants. The sub-index curves for each parameter was drawn to establish a relationship between the leachate pollution and the strength or concentration of the pollutant which was reported by [13]. Table 2.0 showed the characteristics and LPI of leachate from Yenagoa Central Waste dumpsite for the two analytical regimes.

Table 2.0: Characteristics and LPI of leachate from Yenagoa Central Waste Dumpsite during March, 2019

Parameters	Laboratory Data		Individual Pollution rating {Sub-index Value Pi)		Variable Weights (wi)	Cumulative Pollution Rating (piwi)	
	MARCH, 2019	DEC., 2019	MARCH, 2019	DEC., 2019		MARCH, 2019	DEC., 2019
pH	7.7	7.58	5	5	0.055	0.275	0.275
TDS	6,125	623	12	5	0.05	0.6	0.25
NO_3	0.4	0.3	5	5	0.051	0.255	0.255
BOD	10	12	5	6	0.061	0.305	0.366
COD	366	337	13	12	0.062	0.806	0.744
Cu	0.02	-	5	-	0.05	0.25	-
Zn	0.11	0.08	5	5	0.056	0.28	0.28
Fe	8.04	4.77	5	5	0.045	0.225	0.225
TC	2800000	30000000	100	100	0.052	5.2	5.2
Total					**0.482**	**8.196**	**7.595**
LPI						**17.004**	**15.757**

Note: All values are in mg/L except pH and TC; TC means total coliform count (CFU/mL)

Nine (9) out of the Twenty-three (23) variables were used for the LPI analysis because they were the available data. When the data for all the leachate pollutant variables included in LPI is not available, the LPI can be calculated using the data set of the available leachate pollutants [17]. Therefore, Eq. 2 above was used to calculate the Leachate Pollution Index.

This study adopted the Indian standard of leachate disposal since such standards are very scarce in Nigeria. According to [13], the leachate disposal standards had a value of 7.378 in his study as presented in Table 3.0 below.

Table 3.0: Characteristics and LPI of Leachate Disposal Standard

S/N	Parameters	Leachate Disposal Standard	Sub-index Value	Variable Weights	Overall Pollutant Rating
1	Cr	2.0	9	0.064	0.58
2	Pb	0.1	5	0.063	0.32
3	COD	250	10	0.062	0.62
4	Hg	0.01	6	0.062	0.37
5	BOD_5	30	6	0.061	0.37
6	As	0.20	5	0.061	0.31
7	Cyanide	0.2	6	0.058	0.35
8	Phenol	1.0	5	0.057	0.29
9	Zn	5.0	6	0.056	0.34
10	pH	5.5-9.0	5	0.055	0.28
11	TKN	100	6	0.053	0.32
12	Ni	3.0	10	0.052	0.52
13	TC	No standard	-	0.052	-
14	NH_3-N	50	7	0.051	0.36
15	TDS	2100	7	0.050	0.35
16	Cu	3.0	18	0.050	0.90
17	Chlorides	100	8	0.049	0.39
18	Total Iron	No standard	-	0.045	-
Total					**6.67**
LPI					**7.378**

Note: All values are in mg/L except pH and C; TC means total coliform (CFU/mL) Source: Thirteen International Waste Management and Landfill symposium, Proceedings Sardine, 2011[13].

This implied that any LPI value which falls below the stipulated standard (7.378) is accepted, while any value above the standard is not accepted.

Figure 1.0 below gives a graphical representation of LPI values for each sampling regime on the landfill and that of the standard value.

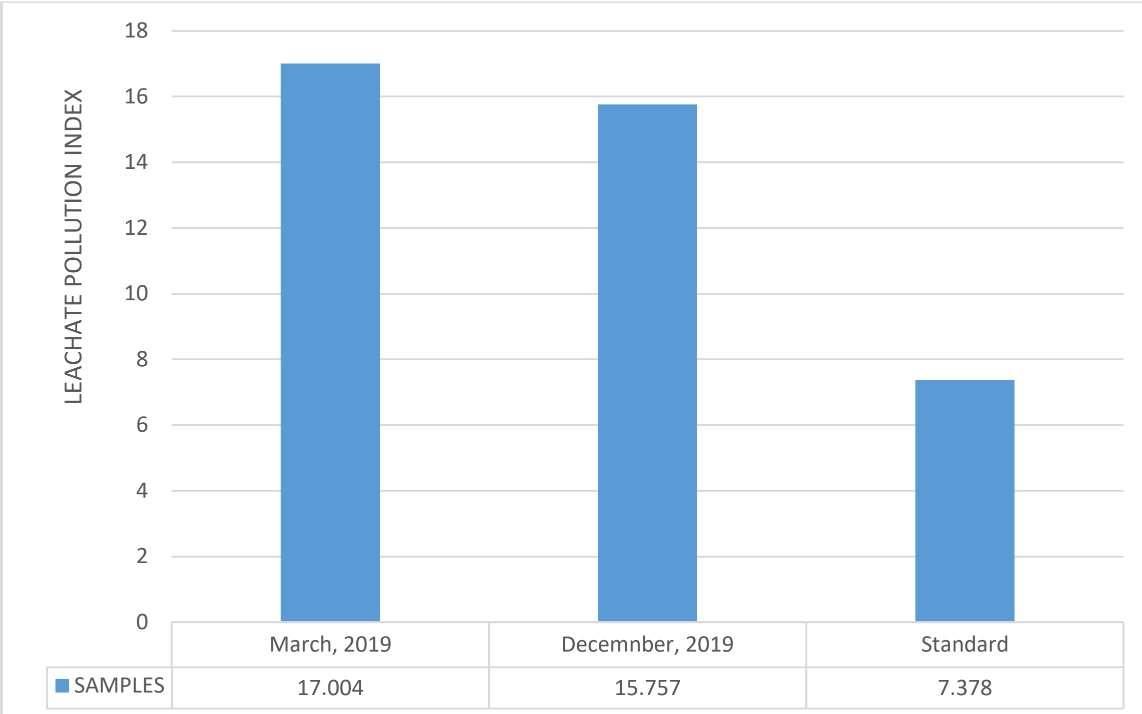

Figure 1.0 Leachate Pollution Index at YCWD

As clearly shown in the chart, the comparison of LPI values for the two sampling regimes showed that March, 2019 has the highest LPI value (17.004), while the December, 2019 analysis has the least value (15.757). This implied that the leachate of this dumpsite during the two sampling regimes were having the potential to contaminate and subsequently pollute the environment when released without treatment. The data also showed that the toxicity of leachate was more during the March analytic regime, which meant that it had more pollution potential than that of the December analysis, which meant that the leachate produced from YCWD was toxic during the first and last quarters of the year 2019.

Though when compared to other landfills' leachate pollution indices studies conducted by [19], the 17.004 and 15.757 LPI values were below the LPI values of 34.02 and 31.80 gotten from an active and an abandoned dumpsite respectively. This showed that the leachate of this study was not as toxic as those from the latter. However, the leachates produced from this study in the two sampling regimes were highly contaminated when compared to leachate disposal standards for inland surface water, therefore, adequate monitoring and treatment is required.

5.0 CONCLUSION

Like many other landfills studied previously, YCWD also showed leachate with very minimal presence of heavy metals within it, hence their absence in the computation of the LPI. This may have been as a result of the high pH of the leachates which may have reduced solubilization of metals [20].

LPI as a hazard identification tool was used to assess the leachate pollution potential of YCWD.

In the present study, the LPI values of 17.004 and 15.757 indicated that the waste deposited has not yet stabilized.

A comparison of the LPI values of this study i.e. 17.004 and 15.757, with the Indian standards set for the disposal of leachate disposal standard for inland surface water indicated that the leachates generated from the landfill were highly contaminated and will have to be treated so that the LPI value reaches below 7.378 before allowing it to discharge into the environment.

This landfill site do not have any base liner or leachate collection and treatment system, hence a properly designed monitoring program should be initiated and maintained on a continuous basis to timely identify cases of leachate pollution.

This poses a serious threat to public health and the environment, therefore, there is an urgent need for the Bayelsa State Government to swing into remediation action in the interest of the citizens, particularly for those who come in contact with it daily.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

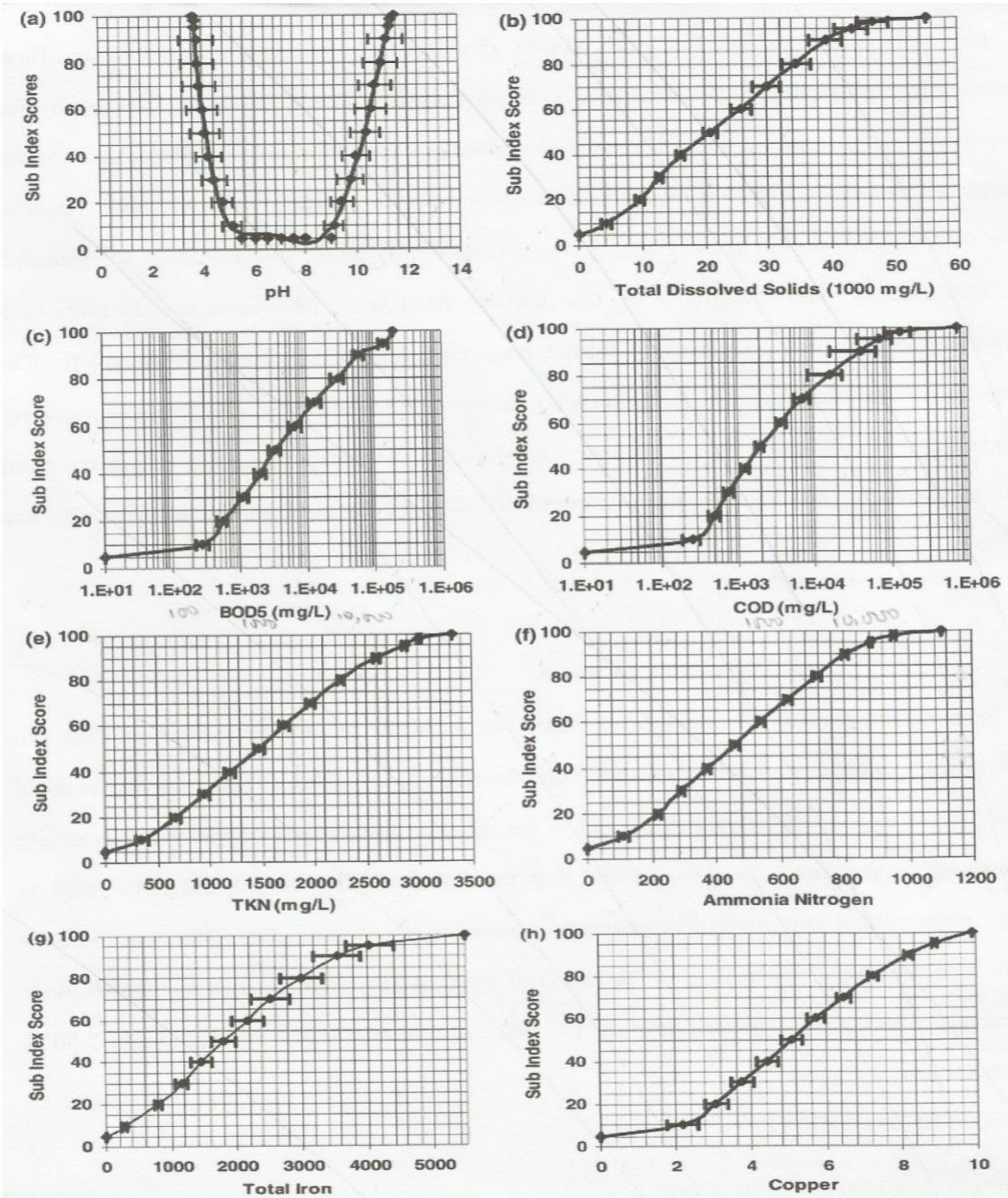

Figure 2.0: The average sub-index curves of pollutants [13]

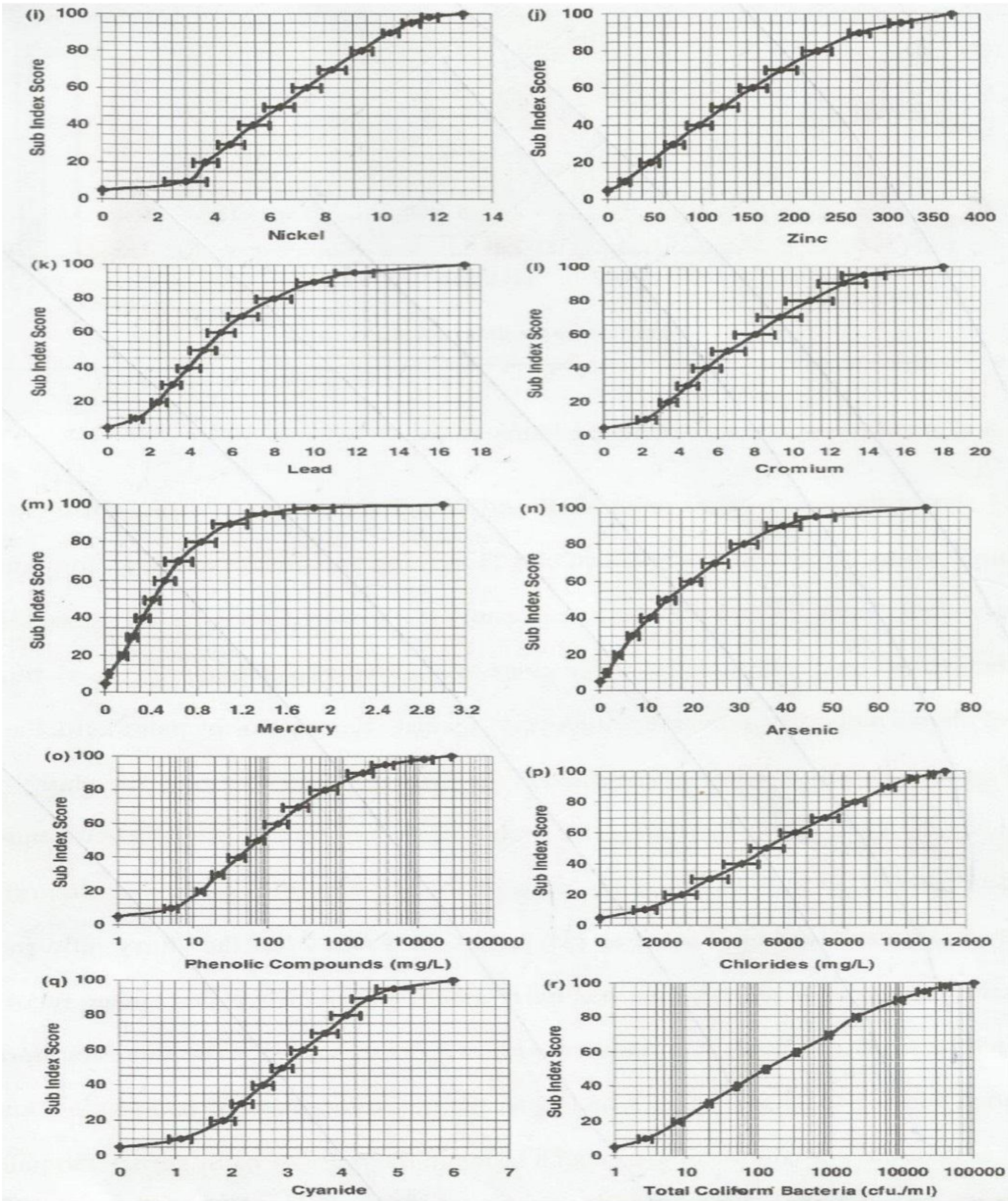

Figure 3.0: The average sub-index curves of pollutants [13]

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