Advances in Research
9(3): 1-6, 2017; Article no.AIR.29620
ISSN: 2348-0394, NLM ID: 101666096

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Investigating a Southern Manchester Landfill Leachate

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Authors' contributions

This work was carried in collaboration of both authors. Author ANN designed the study, collected and analyzed the data used in this work and wrote the first draft of the manuscript. Author CDH managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2017/29620
Editor(s):
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Complete Peer review History: http://www.sciencedomain.org/review-history/18704

Short Research Article

Received 21st September 2016
Accepted 3rd January 2017
Published 20th April 2017

ABSTRACT

The leachate was analyzed for physicochemical parameters and Total Organic Carbon (TOC). The pH and electrical conductivity (EC) levels were determined using pH meter and EC meter respectively, whilst TOC analyzer and Palintest Photometer were used to collect TOC and Ammonia (NH_3) concentrations respectively. The results were evaluated in relation to soil standards recommended for soil remediation.The physicochemical characteristic of the leachate from the landfill suggests that they were more acidic (average pH = 6.86) in nature, with EC range of 540 to 1420 µS/cmwhile the TOC values were far above the regulated limit. High NH_3 concentration values of up to 2.42 mg/L attests to the humic nature of this Landfill.The high concentration of colour observed could be due to the presence of organic substances. More landfill leachate parameters need to be monitored if a holistic analysis of this particular landfill leachate must be ensured.

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Keywords: Landfill; leachate; physicochemical parameters; TOC analyzer; EC meter; pH meter; Palintest photometer; remediation.

1. INTRODUCTION

Pollution emissions from landfills[1] are amongst the prevalent landfill environmental problems [1-2]. They can be categorized into emissions to the atmosphere (noise, odour, dust, bio-aerosol and biogas) and emissions to the water environment comprising the potential emissions of leachate and contaminated surface water run-off to watercourses (ditches, streams, and rivers) or groundwater in permeable strata below the landfill [3-4].

Leachate is the liquid residue resulting from the various chemical, physical and biological processes taking place within the landfill [5]. Landfill leachate is generated by excess rainwater percolating through the waste layers in a landfill [5]. A combination of physical, chemical and microbial processes in the waste transfer pollutants from the waste material to the percolating water [6]. After a landfill site is closed, a landfill will continue to produce contaminated leachate and this process could last for 30-50 years [5].

The constituents of a typical MSW landfill leachate depends on the types and amounts of waste land-filled, landfill age and environmental conditions [7]. Generally, leachate is characterized by high biochemical oxygen demand (BOD) and high concentrations of organic carbons, nitrogen, pH, ammonia, chloride, iron, manganese, and phenols [3,8]. Others include solvents, pesticides, and heavy metals [3] as well as strong colour and bad odour [9]. A study by Kjeldsen et al. [10] revealed low concentrations of heavy metals and is in contrast with ammonia which does not decrease and often constitute long term pollutant in leachate.

In this study, the monitored components of leachate include concentrations of ammonia (NH_3) and total carbon (TC) which is equal to the sum of the concentrations of inorganic carbon (IC) and total organic carbon (TOC). Also monitored are the physicochemical parameters (pH and electrical conductivity) of the leachate. Due to lack of monitoring device, it was not possible to measure the concentrations of other hazardous components of landfill leachate such as dissolved-phase heavy metals. The monitored parameters were compared with their standard limits and existing data of other landfill sites.

The requirement to quantify the concentrations of the studied landfill gases and the leachate components was prompted by the complaints received from the inhabitants of the halls built on and around the landfills concerning strange odours from the sites. There is also fear of potential hazards of explosion, asphyxiation and toxicity from methane, carbon dioxide, and volatile organic compounds respectively. For example, on July 13, 2012 more than 20 homes built on site 1 had to be evacuated because of a methane scare. Householders, including families with children, were told to leave their homes just before 8pm after methane alarms sounded. The special alarms were set up after the highly-flammable gas was discovered in the area leaking from the site. About 50 residents were told they could return to their homes around midnight after tests showed the methane was at safe levels. Fire-fighters were called to the scene to help the council and other agencies with the evacuation.

2. METHODOLOGY

Both in-situ and ex-situ analysis of waste-water samples collected from the solid waste base via 50mm boreholes was undertaken to determine the pH and electrical conductivity level in different boreholes using pH meter and EC meter respectively. In order to try to detect leachate, ex-situ analysis of water samples for dissolved organic and inorganic matters was conducted. While TOC machine was used to measure total dissolved carbon (organic and inorganic), Palintest photometer was used to measure dissolved ion (NH_3).

TOC analyzer uses the 680℃ combustion catalytic oxidation method[2]. This method has the capacity to efficiently oxidize hard-to-decompose organic compounds, including insoluble and

[1] *Sanitary landfill is a process in the solid waste management system. It can be defined as ''a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary [9].*

[2] http://www.shimadzu.com/an/toc/lab/toc-l4.html

macromolecular organic compounds. It achieves total combustion of samples by heating them to 680℃ in an oxygen-rich environment inside TC combustion tubes filled with a platinum catalyst. As this utilizes the simple principle of oxidation through heating and combustion, pre-treatment and post-treatment using oxidizing agents are unnecessary, which enhances operability. The carbon dioxide generated by oxidation is detected using aNondispersive infrared (NDIR) gas analyzer. By adopting a newly-designed, high-sensitivity NDIR, the TOC-L series achieves high detection sensitivity, with detection limit of 4μg/L, the highest level for the combustion catalytic oxidation method. Fig. 1 is a schematic diagram showing TOC measurement using the 680℃ combustion catalytic oxidation method and the NDIR method.

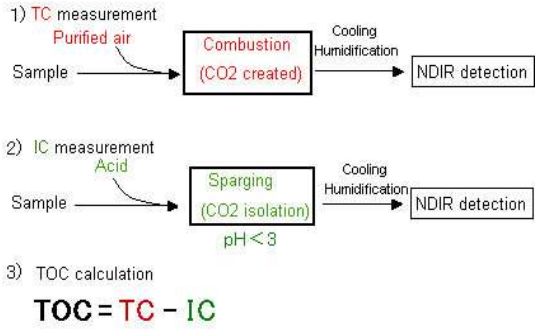

Fig. 1. TOC measurement using the 680℃ combustion catalytic oxidation method and the NDIR method

The sample is delivered to the combustion furnace, which is supplied with purified air. There, it undergoes combustion through heating to 680℃ with a platinum catalyst. It decomposes and is converted to carbon dioxide. The carbon dioxide generated is cooled and dehumidified, and then detected by the NDIR. The concentration of TC (total carbon) in the sample is obtained through comparison with a calibration curve formula. Furthermore, by subjecting the oxidized sample to the sparging process, the IC (inorganic carbon) in the sample is converted to carbon dioxide, and the IC concentration is obtained by detecting this with the NDIR. The TOC concentration is then calculated by subtracting the IC concentration from the obtained TC concentration.

The Palintest NH_3 test is based on an indophenol method. NH_3 reacts with alkaline salicylate in the presence of chlorine to form a green-blue indophenol complex. Catalysts are incorporated to ensure a rapid colour development. The reagents are provided in the form of two tablets for maximum convenience. The test is carried out by adding one of each tablet to a sample of the water. The intensity of the colour produced in the test is proportional to the NH_3 concentration and is measured using a Palintest Photometer. The reagents and equipment include Palintest Ammonia No 1 Tablets, Palintest Ammonia No 2 Tablets, Palintest Automatic Wavelength Selection Photometer and Round Test Tubes (10 ml glass). The test instructions are:

1. Fill test tube with the sample to the 10 ml mark
2. Add one Ammonia No 1 tablet and one Ammonia No 2 tablet, crush and mix to dissolve.
3. Stand for ten minutes to allow colour development.
4. Select Phot 4 on Photometer to measure Ammonia (mg/l) or select Phot 62 on Photometer to measure Ammonium (mg/l NH_4).

Note that the Palintest Ammonia test provides a simple method of measuring ammonia (ammoniacal nitrogen) over the range 0 – 1.0 mg/l N. More information on this can be found in the Palintest Test Instruction manual.

2.1 Investigated Site

This is a former ‘brickworks and associated clay pits’ which became a landfill site in the 1940s, for the dumping of household, commercial and industrial waste materials. It ceased to be used as landfill in about 1975. Residential properties were built on the site during the 1970s. During the late 1990s, gas was found to be leaking into some of the properties. In 1999, a 'venting trench' was built to prevent gas leaking into the houses. Although it helped, the problem was not completely resolved. But excavations within the last few years have established some of the properties are on top of tipped material and it was formally declared 'contaminated land'. Physical site investigation works have confirmed the presence of such wastes in the eastern portion of the tip, although limited information is available for the remainder of the Landfill area. A further landfill site comprising the infilled section of an abandoned railway cutting (southern strip) is situated immediately to the south of the Landfill Site and is reported to have been filled with inert wastes only. Also produced in the site is leachate.

3. RESULTS AND DISCUSSION

Leachate samples of MSW landfill site located in Southern Manchester, UK was analysed for the physicochemical parameters to estimate its pollution potential. The concentrations of pollution parameters examined in the studied landfill leachate are presented in Tables 1 and 2 as was collected in November 2012 and February 2013 respectively.There is variability in the concentration of the measured parameters, however; some were more variable than the others during the monitoring periods (see Table 3).

The analysis of the samples collected reveals some level of compliance with Regulated Standards, however, this was not consistent as significant deviations were also observed. The mean pH of the whole landfill was 6.85 whilst its pH ranged from 6.67 to 7.13 which falls within the WHO regulated standards. The pH values are neither consistent with those published by previous authors [11-14] nor up to its expected value given the age of the landfill. Ideally, its pH is supposed to be greater than 7.5, however; it is in the range of that of an intermediate landfill (5-10 years old) [5]. This behavior could be due to the quantity and type of waste land-filled and level of degradation. The values are fairly constant with little variations which are characteristic of a stabilized leachate [5].

The colour of the leachate samples was dark-brown. Associated with the leachate is a malodourous smell, due mainly to the presence of organic acids which come from high concentration of organic matter when decomposed. The high concentration of colour is due to the presence of organic substances [5,15]. Since this landfill is an old one (up to 50 years old), the leachate produced will normally be classified as stabilized [5]. Such leachates contain high levels of organic substances such as humic and fluvic compounds- which give the leachate its characteristic dark colour [16].

Table 1. Result of analysis of waste-water samples collected on 01/11/2012

S/N	Sample	Total carbon (ppm)	Inorganic carbon (ppm)	Total organic carbon (ppm)	Concentration of NH_3 (mg/l)	Electrical conductivity (Siemen)	pH
1	BH5	137.00	94.31	42.69	0.83	1420	6.90
2	BH8	138.80	75.40	63.40	1.82	1060	6.92
3	BH9	105.80	63.76	42.04	1.20	1020	6.86
4	BH10	105.70	59.41	46.29	1.11	830	6.30
5	BH11	153.8	85.63	68.17	2.42	1240	7.11

Table 2. Result of analysis of waste-water samples collected on 07/02/2013

S/N	Sample	Total carbon (ppm)	Inorganic carbon (ppm)	Total organic carbon (ppm)	Concentration of NH_3 (mg/l)	Electrical conductivity (Siemen)	pH
1	BH5	119.58	54.13	65.45	1.20	1190	7.13
2	BH8	61.14	27.44	33.70	0.15	540	6.96
3	BH9	72.37	30.70	41.67	0.61	620	6.95
4	BH10	81.67	34.84	46.83	1.21	650	6.81
5	BH11	137.69	51.18	86.51	1.21	970	6.67

Table 3. Statistical analysis – Analysis is for the two monitoring periods (Tables 1 and 2)

Parameter	Range	Mean ($\bar{y}$)	S.D =$\Sigma(y-\bar{y})^2/n$	Standard limit
pH	6.30 - 7.13	6.86	0.24	—
EC (µS/m)	540 - 1420	954	290.83	400 (WHO)
NH_3 (mg/l)	0.15 – 2.42	1.18	0.62	—
TOC (ppm)	33.70 – 86.51	53.68	16.40	30000 (EU)

S. D. = Standard deviation, y = variable or test result, $\bar{y}$ = Mean value, n = no. of plots used, WHO = World Health Organization Standard, EU = European Union Standard

The concentration of ammonia ranges from 0.83 – 2.42 mg/l in November 2012 and 0.15 – 1.21 mg/l in February 2013. Natural levels of ammonia in groundwater are usually below 0.2 mg/l [17]. Higher natural contents (up to 3 mg/l) are found in strata rich in humic substances or iron or in forests [18]. Taste and odour problems as well as decreased disinfection efficiency are to be expected if drinking-water containing more than 0.2 mg/l of ammonia is chlorinated [19]. The threshold odour concentration of ammonia at alkaline pH is approximately 1.5 mg/l, and a taste threshold of 35 mg/l has been proposed for the ammonium cation [20], however; at these levels, it does not constitute health risk. No guideline values exist for ammonia because, it has been found to occur in drinking-water at concentrations well below those of health concern [21].

The ability of a solution to conduct an electrical current is governed by the migration of solutions and is dependent on the nature and numbers of the ionic species in that solution – a property known as electrical conductivity [22]. It is a useful tool to assess the purity of water. The EC of the collected samples ranged from 540 to 1420 µS/cm. The EC values for the tested leachate samples are very much above the WHO level of 400 µS/cm.

The TOC values for leachate at landfill site ranged from 33.70 ppm to 86.51ppmduring the entire monitoring periods. According to the EU's rules [23] for waste prevention and waste management in compliance with environmental, human health and sustainable development, the permissible standard limit of TOC in landfill sites is 30000 ppm. By comparison, the TOC values recorded for the leachate samples were far below the permissible standard limit.

4. CONCLUSIONS

The result shows that it was only the Electrical Conductivity out of all the measured landfill leachate parameters that exceeded the set limit. The concentration of Ammonia was quite high, however; even at that level, it was still incapable of constituting hazards to human health. The pH values of the leachate against our expectations were within the range of that of an intermediate landfill in spite that the investigated landfill is a very old one. This, however; suggests that the level of waste disposed in the landfill may be low or that waste degradation may not have reached its enhanced stage (probably due to low moisture content) or both.

Given the limitation of fund which resulted to inadequacy of monitoring tools, it was not possible to monitor all parameters of interest. There is, therefore, a requirement to revisit the site so as to take into consideration those parameters that were left out. Further research will warrant better characterization of the Leachate of this landfill site.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Available:http://www.lenntech.com/applications/drinking/standards/eu-s-drinking-water standards.htm#ixzz3q3XZwcap

Peer-review history:
The peer review history for this paper can be accessed here:
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