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EFFECT OF WASTE DUMP SITE ON GROUND WATER QUALITY IN HURUMA ESTATE, ELDORET, KENYA.

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Abstract

Water pollution has been associated with open waste dumping across the globe. This study work gives the effect of open waste dump on groundwater quality at Huruma, Eldoret Town, Kenya. Ground water and leachate samples from the open waste dump site were collected and analyzed in the laboratory for physical and chemical characteristics. All the parameters were determined based on the American Standard Methods for Examination of water and wastewater. From the results obtained, it was found that the mean values of TDS, DO, SO4+, pH, COD and BOD are 17.73 mg/L, 5.94 mg/L, 0.05 mg/L, 6.54, 13.62 mg/L, and 6.07 mg/L respectively. For leachate samples, mean values for TDS, SO4+, pH, COD and BOD are 89.25 mg/L, 0.36 mg/L, 7.63, 24.56 mg/L, and 13.83 mg/L respectively. Most of the parameters fall within WHO drinking water standards (except pH, COD and BOD). Open waste handling, controlling and monitoring techniques must gear towards achieving quality environmental condition for many to live in. This will go a long way to protecting natural resources such as water that are degraded by these open wastes.

Key words: *Waste, Dump site, Ground Water, Leachate*

Introduction

Water is an indispensable resource outside which human existence will become unbearable. It is used for various purposes such as for domestic, industrial, agricultural and commercial purposes. Groundwater is the underground water that occurs in the saturated zone of variable thickness and depth, below the Earth's surface (Cuthbertet al., 2019). Groundwater comes from precipitation, which must filter down through the vadose zone to reach the zone of saturation, where groundwater flow occurs (Gleeson et al., 2016). The rate of infiltration is a function of soil type, rock type, antecedent water and time. Groundwater contains more dissolved constituents than surface waters and the ground water if polluted; treatment to make it safe is difficult and relatively expensive. The rainfall that percolates below the ground surface passes through the voids of the rocks and joins the water table. These voids are generally inter-connected, permitting the movement of the groundwater (MacDonald et al., 2021). The occurrence of groundwater therefore, depends largely upon the type of formation, and upon the geology of the area (Reese, 2014). The meaning of quality as frequently used in relation to water appears to be confusing to many people. As a result of this confusion drinking water standards have been developed to define the quality of water that is safe and acceptable to the consumer. Most drinking water standards therefore set limits for organisms or chemical substances that are harmful, and potentially hazardous or obnoxious to consumers. Materials termed obnoxious are those through harmless to health, has an adverse effect on the use of the water due to its taste, colour, odour, turbidity, corrosivity or other unbearable properties.

Landfills have served for many years as disposal sites for all types of wastes namely residential, commercial and industrial. Physical, chemical, and biological processes bring about the overall decomposition of the wastes. One of the by-products of these mechanisms is leachates. The environmental problem from landfills is the leachates from the site which contaminates ground water, (Jing et al., 2021). Three important attributes that distinguish any source of ground water

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contamination are the degree of localization, the loading history, and the kinds of contaminants.

The loading history describes how the concentration of a contaminant or its rate of production varies as a function of time at the source. Factors which influence leachate composition include the types of wastes deposited on the landfill and the amount of precipitation in the area among others. The rates of biological and chemical activities in the landfill can also affect leachate quality by altering the way the waste dissolves in or migrates with leachates (Zhiyong et al., 2016). Wastes are mainly disposed off to the landfill because it is the simplest, cheapest and most cost-effective method of disposing off wastes. In most low to medium income developing nations like Kenya most of the generated waste goes to landfill. Due to this, landfill is likely to remain a source of groundwater contamination in foreseeable future. Understanding the quality of groundwater is important as it is the main factor determining its suitability for drinking, and other major purposes.

The term leachate describes any liquid percolating through the deposited waste. The quantity of leachate produced depends on the liquid fraction of wastes, rainfall, and surface water inflow. Leachate breakout is caused by high leachate levels within the waste resulting from uncontrolled inflow of water into the site. On existing sites, leachate may escape through weaknesses in the capping layer, or through the soil covering particularly around the edges of the landfill. There are some toxic effects from leachates but in many cases it is the water-logging and anaerobic soil conditions that cause problem to vegetation. Leachate has the potential to impact negatively on surface and groundwater thereby affecting water quality for humans and wildlife. Leachate contain a host of toxic and carcinogenic chemicals, which may cause harm to both humans and the environment. The use of contaminated water for irrigation can decrease soil productivity, contaminate crops, and make toxic pollutants go up the food chain (Anand and Sankar, 2022). Dumpsites emit obnoxious odours and smoke that affect people living around, or closer to them. Dumpsites maybe a source of chemical contamination via off site migration of gases and the particles and chemicals adhering to dust.

Contamination of soil and groundwater may lead to pollution of indoor air the case of volatile organic chemicals and in the case of consumption of home-grown vegetables as well. These conditions are worse in dry weather because of extreme temperatures, which speed up the rate of bacterial action on biodegradable organic materials.

Water quality may be described as water whose characteristics make it suited to the needs of the users. A body of water is said to be polluted when it is adversely affected due to the addition of foreign materials. When it is unfit for its intended use, water is considered polluted.

Generally, water quality can be viewed in terms of its physical, chemical and biological parameters (Anna et al., 2023). Ground water is about 210 billion m^2 including recharge through inflection, seepage and evapotranspiration. Out of this nearly one third is extracted for irrigation, industrial and domestic use, while most of the water is regenerated into rivers (Jasechko and Perrone, 2021). Over 98% of the fresh water in the earth lies below the surface. The remaining 2% is what is in lakes, rivers, streams and reservoirs.

Groundwater acts as a reservoir and is the source of water for wells and rural domestic use. It is replenished by precipitation through rain, snow and others (Jasechko and Perrone, 2021)

Today, human activities are constantly adding industrial, domestic and agricultural wastes to ground water reservoirs at an alarming rate. Groundwater contamination is generally irreversible. Although the soil mantle through which water passes, acts as an adsorbent retaining a large part of colloidal and soluble ions with its cation exchange capacity, but ground water is not completely free from the menace of chronic pollution.

Landfill sites may differ enormously in the conditions that render them hazardous, and conditions that determine the exposure to health risks. Such conditions may include the types, quantities, and age of the waste present and site management and engineering practices.

According to Wijekoon *et al.,* (2022), the global annual solid waste generation is increasing due to economic growth, urbanization, demographic growth

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and changing life styles. This has made waste management to be among the major challenges of the waste dumping. Studies have shown that African countries are experiencing rapid development and are now faced with huge amount solid waste which has direct effect on the environment (Bello *et al*., 2016). A study by Njoroge et al, (2014) has given rapid urbanization, industrialization, population growth and increased waste generation of solid waste as a major public health and environmental concern in Kenya. Solid waste management is tough and very expensive especially to the urban poor who cannot afford the services and hence left to deal with waste disposal on their own.

Polluted water acutely affects soil fertility by killing bacteria and soil micro-organisms. Groundwater increases alkalinity in the soil. Groundwater pollution affects plants metabolism and disturbs the whole ecosystem. Open dumps are well known to release large amounts of hazardous chemicals to nearby groundwater, surface water and soil. It is known that such releases contain a wide variety of potential carcinogens and potentially toxic chemicals that pause a threat to public health. The amount of leachates produced from open waste dump depends on the fill. Once the open wastes has reached its capacity to hold water, the leachate that is formed can create serious water pollution problem.

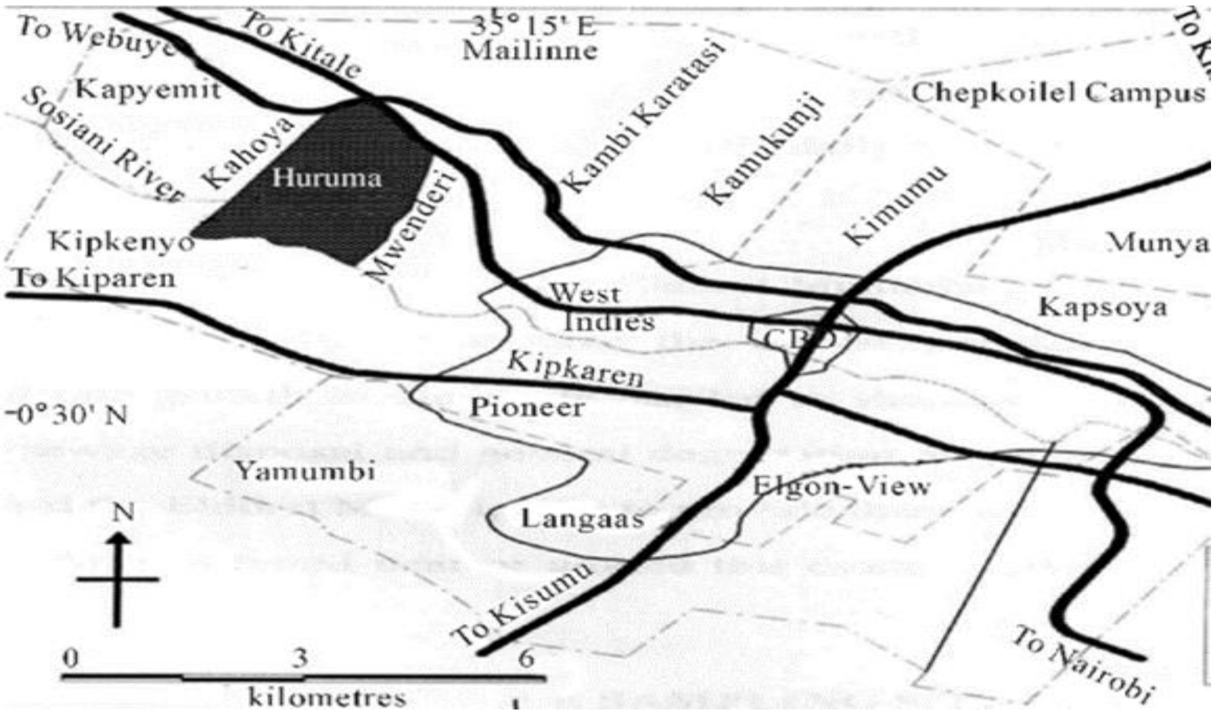
The presence of large quantities of mixtures of potentially hazardous chemicals in open wastes dumping sites close to residential areas has increasingly caused some significant groundwater and public health concerns. The concerns have led to a substantial study on the quality of ground water and effects associated with open waste dumping site.

Study area

Eldoret town is in the Western part of Kenya, in Uasin Gishu County It is located 263 km from Nairobi, the capital of Kenya. Eldoret is situated at a latitude of 0.5143N and longitude of 35.2659E. The town is 2103 m above sea level. The current population of Eldoret according to the official records of the 2019 census final results is 475,716 (KNBS, 2019). Huruma area of Eldoret experiences the injection of large quantities of effluents due to improper domestic waste management that creates poor sanitary conditions. Water related diseases are the most critical health problems in the estate. The major sources of water in the town are rain water, piped water and hand dug wells.

Figure 1

Map of Study Area



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Materials and Methods

Sample Collection

Water samples were collected using 1litre plastic bottles with screw capped tops from the existing boreholes and shallow wells near the dumpsite. Leachate sample were also collected from the dumpsite vicinities within the study area at Huruma, Eldoret. The container of the samples were washed with soap solution and rinsed severally with distilled water before the samples were collected at three different locations. To maintain the natural chemistry of the samples it was preserved with preservation methods which includes pH control, refrigeration and protection from sunlight penetration.

Leachate Characteristics and Groundwater Parameters Measurement

The following leachate and groundwater parameters were determined for this study. They were pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride, Suphate ($S0_4$).

The samples containers were thoroughly washed with detergents, rinsed with distilled water and allowed to dry. At the point of collection, each container was rinsed again with the sample before sampling.

All the physiochemical parameters were determined based on the American Standard Methods for Examination of water and wastewater (APHA, 2017). The available standard procedures and apparatuses listed were used. The materials and equipment used include: Distilled water, pH meter, Conductivity meter, Beakers, Volumetric flask, Pipette, Spectrometer.

Determination of pH

Apparatus used were pH meter with electrode, thermometer, beaker, stirrer. The pH meter was turned on and was standardized with buffer solution of pH 7 at 25°C representing absolute neutrality and pH 14 after the calibration. The electrode was removed and rinsed with distilled water. The electrode was immersed into some quantities of the sample in the beaker. The reading of the result was displayed on the screen of the pH meter and was recorded. The electrode was removed and rinsed with distilled water. This same procedure was repeated for other samples.

Determination of Total Dissolved Solid (TDS)

Apparatus

The following apparatus were used in the study: Conductivity meter, beakers.

Procedure

Some quantity of the water sample was measured into a beaker. The meter was switched on and the electrodes were rinsed with distilled water and then dipped in sample solution. The exact conductivity is immediately shown on the meter depending on the conductivity of the waste water. The button of the total dissolved solid on the conductivity meter was pressed and the reading displayed on the screen of the conductivity meter, the result read and recorded. The electrode of the conductivity meter was removed and rinsed with distilled water. This same procedure was repeated for all the samples.

Chloride Determination

Apparatus

The following apparatus were used in the study: Burettes, Pipettes, Erlenmeyer flasks and measuring cylinder.

Procedure

1ml of potassium dichromate indicator solution was added to the sample and mixed. From a burette silver nitrate ($AgN0_3$) was added until the yellow colour changes to a brownish tinge. The solution was titrated with nitrate solution with constant stirring until only the slightest perceptible brownish colouration persists. 50ml of the sample was and diluted to 100ml before titration. These Steps were repeated on 100ml distilled water blank to allow for the presence of chloride in any of the reagent and for the solubility of silver chromate.

To calculate the concentration of chloride ions, the following formula was applied:

$$\text{Chloride as Cl} = \frac{100(V_1 - V_2)mgl}{Volume\ of\ sample}$$

Where; V_2 = volume of silver nitrate required by the blank

V_1 = volume of silver nitrate required by the sample

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Biochemical Oxygen Demand (BOD) Determination

Apparatus

The following apparatus were used: BOD bottles of 300ml capacity, Air incubator (20°C $\pm$ 1°c), Stir plate, stir bar, ring stand, burette, 200ml beaker, burette holder and 500ml cylinder.

Procedure

Diluted water was prepared by mixing 1ml of phosphate buffer solution, magnesium sulphate solution, calcium chloride solution and ferric chloride solution in 100ml of water. Then 300ml reagent bottles were filled with samples and poured into a 500ml measuring cylinder and the same was filled with diluted water and mixed with the sample in the cylinder. Finally, the bottles were filled with the mixed water samples and the dissolved oxygen was determined as described on the dissolved oxygen (DO) determination. The bottle was washed and filled with the remaining solution of the mixed sampled water. This was incubated at 20°C for 5-days and determined dissolved oxygen.

Dissolved Oxygen (DO) Determination

Apparatus

Measuring cylinder, Conical flasks, Burette and burette stand and funnel.

Procedure

Fresh samples were opened and 285ml of each was measured into labeled bottle. 1ml of manganous sulphate solution, 1ml of Alkali iodide Azide solution, 1ml of concentrated H_2S0_4 was added accordingly and the mixture was swirled very well. About 200ml of all the treated samples were measured and titrated against Na_2SO_3. $5H_20$ until a colourless solution appeared with help of 3 drops of starch indicator. The readings were taken and recorded. This same procedure was repeated for other samples.

Determination of Chemical Oxygen Demand (COD)

Apparatus

COD reactor with cover and test tube rack, Spectrophotometer, Heat resistant gloves, 50ml cylinder, Pipettes (5 and 10ml) and pipette bulbs, 100ml volumetric flask and 150ml beakers.

Reagents and Chemicals

Standard potassium dichromate solution, 0.0417m (0.25N): 12.259g of $K_2Cr_2O_7$ was weighed and dissolved and diluted to 100ml. The $K_2Cr_2O_7$ was then transferred into a reagent bottle and stored in the refrigerator.

Standard ferrous ammonium sulphate (FAS) or Ammonium iron (11) sulphate titrant approximately 0.25m (0.25N): 98g of $FeS0_4$. $(NH_4)_2S0_4.6H_20$ was weighed and dissolved in 1000ml of distilled water. The solution was transferred into a reagent bottle. 20ml of concentrated H_2S0_4 was added and the solution was allowed to cool. The solution was diluted to 1000ml and stored in the refrigerator. It was Standardized against $K_2Cr_2O_7$ solution. Mercuric sulphate, crystals or powder. Sulphuric acid (specific gravity 1.84). Sulphuric acid – silver sulphate solution 15g of powdered silver sulphate ($Ag2S0_4$) was dissolved in 30ml of concentrated H_2S0_4. Phenanthroline ferrous sulphate indicator (i.e ferrocene indicator). 1.48g of phenanthroline was weighed + 0.70g of ferrous sulphate. The combination was dissolved in 100ml distilled water and stored in an indicator bottle.

Procedure: Open Reflux Method

50ml of distilled water was measured and poured into a conical flask as the blank. The 50ML of each sample was also measured and transferred into labelled conical flasks. 25ml of $K_2Cr_2O_7$ solution was added to each flask. Approximately 1g mercuric sulphate (Hg_2S0_4) was added. 5ml of concentrated H_2S0_4 containing Ag_2S0_4 was also added into the entire sample (in a bowl of water to avoid excessive heat loss). The reflux apparatus was set and 70ml of concentrated H_2SO_4 was added through the condensers and boiling beads were added. The mixture was allowed to reflux for 2 hours with small beakers placed over the open and of the condensers to prevent intrusion of foreign materials.

After refluxing, each sample was transferred to a 500ml beaker and the mixture was made up to 300ml using distilled water and cooled to room temperature under a tap and mix well using 2 to 3 drops of ferrocene (ferroin) indicator was added and the solutions were titrated against ferrous ammonium sulphate (FAS).

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Results and Discussion

The laboratory analysis was conducted for the pH, TDS, chloride, sulphate BOD and COD of leachate and groundwater using standard devices.

Table 1 are the results of the analysis of samples of leachate and groundwater from different places within Huruma estate in Eldoret, Town close to some waste dumpsite. Sites 1, 2 and 3 displayed some physiochemical characteristics of the samples.

Table 1

Leachate Samples from Site 1, 2 and 3.

Parameter	Mean + SD	Site 1	Site 2	Site 3	WHO
pH	7.63±0.57	7.89	8.03	6.98	7.5
TDS mg/L	89.25±5.85	92.39	82.50	92.86	2000
Chloride mg/L	27.95±1.73	28.07	29.62	26.17	250
Sulphate mg/L	0.36±0.09	0.46	0.29	0.32	250
BOD mg/L	13.83±1.53	12.08	14.89	14.52	50
COD mg/L	24.56±1.28	25.01	25.56	23.12	200

Table 2

Ground Water (Wells) Samples from Site 1, 2 and 3.

Parameter	Mean+SD	Site 1	Site 2	Site 3	WHO Standard
pH	6.54±0.24	6.53	6.68	6.41	6.5-8.5
TDS mg/L	17.73±0.69	16.88	18.48	17.82	500
Chloride mg/L	27.67±0.80	27.82	28.44	26.74	250
Sulphate mg/L	0.05±0.06	0.01	0.12	0.03	300
BOD mg/L	6.07±1.00	5.90	5.22	7.08	6
COD mg/L	13.62±0.31	13.98	13.47	13.41	10
DO mg/L	5.94±0.05	5.93	5.89	5	10

The study indicates that some water quality parameters (pH, BOD, COD) exceed the permissible limits for drinking water making water unsuitable for drinking, based on WHO standards. In a view, groundwater contain less amount of suspended impurities due to the presence of different layers of soil, which acts as filter, groundwater however, is normally not exposed to air and thus act as a preservative medium for contaminants. It flows slowly, cleanup is expensive-sometime impossible once contamination has occurred.

It is undoubtedly clear that open waste generally affects ground water resources. Groundwater is clean, tasteless and odourless, especially if it is from deep wells. The pH level is almost constant at 6.41 and 6.68 with little variation.

World Health Organization (WHO) recommends desirable level of 6.5 to 8.5. The lower pH of 6.41 and 6.68 in groundwater (well water) may be due to the presence of organic waste, because organic wastes reduce the pH of water to acidic level. This acidity may generally result from the presence of weak acids

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particularly carbon (IV) oxide (C02) but sometimes, including protein and fatty acids. Other parameters analyzed vary from one sample to another. This however may depend on the depth of the well and its distance from dumpsite.

High concentration of pollutants prevailed in leachate and well water leachate and well water produced during sampling higher concentration of pollutant particularly of productivity, suspended solid, total dissolved solids, phosphate, were found this may be due to the emission form mixed waste but BOD and COD of spring water were greater than nearby well water this may be due to contaminant of waste from its catchments area and due to its stagnation. This could be attributed to groundwater and surface water ingress from the dumping site that promote volatilization of pollutants from active decomposition of waste mass in to leachate emanated from disposal site to the nearby groundwater source.

The dissolved oxygen on the leachate was not detected and in the groundwater was quite low, and cannot support desired aerobic organisms in the study site. This may upset the ecosystem, encouraging development of septic conditions and lead to proliferation of anaerobic biota that may produce anaerobic condition in the groundwater.

Chloride can get into the groundwater from open waste disposal when it comes into contact with rain water and then gains entrance into the aquifer. Results of chloride in analysis in the three different samples varied between 26.17 to 29.62mg/L which is also within WHO recommendations. Most of the water parameter falls within World Health Organization (WHO) recommendation (WHO, 2011). Open waste dumps are known to affect the quality of ground water because they produce gases when decomposing and are washed by percolating and infiltrating rainwater.

Although some agents like dissolved oxygen, total dissolved solids, chloride, contents vary from one sample to another as shown in table 4.1 above, their presence in ground water in Huruma estate do not cause significant Health Hazards.

Conclusion

From the results it was observed that most of the parameters fall within WHO drinking water standard. However, some other water quality parameters (pH, BOD, COD) exceed the permissible limits for drinking water, based on WHO standards. Although some agents like dissolved oxygen, total dissolved solids, chloride, nitrate, iron, hardness, phosphates and sulphate contents vary from one sample to another as shown in table 4.1, their presence in ground water in Huruma do not cause significant Health Hazards.

Open waste handling, controlling and monitoring techniques must gear towards achieving quality environmental condition for many to live in. This will go a long way to protecting natural resources such as water that are degraded by these open wastes. From this frame work it is possible to articulate a position on thorough environmental management procedures to protect ground water resources in Huruma and Eldoret.

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