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Utilization of Locally Available Bacteria in Degradation of Plastics

L. Wanjohi[1*], L. Mwamburi[1], E. Too[1] and J. Kosgei[1]
[1]*Department of Environmental Biology and Health, School of Environmental Studies, University of Eldoret, P.O Box 1125-30100, Eldoret, Kenya*
[*]*E-mail: ruguruwanjohi@gmail.com*

Abstract

Polythene papers have been widely used as packaging material due to their light weight, inertness and low cost. Disposable plastic cups are produced for single use and hence constitute a major source of consumer household plastic waste. The disposal of the polythene bags and disposable plastic cups is a major environmental challenge because they are not easily degraded. An inventory was taken in Lake Nakuru to determine the biodiversity of bacteria of the alkaline waters and their potential utilization in environment restoration through degradation. Samples were collected at five points of the lake selected based on their locations, proximity to fresh water inlets and depth of the lake. The samples were collected once a month for six months in the year 2011. They were kept in a cool box under ice at 4°C and transported to university of Eldoret microbiology lab. Serial dilution was carried out and culturing was done using spread plate method on nutrient agar. The cultures were incubated at 35°C for 24 hours. Sub-culturing was done to obtain pure cultures which were then isolated and identified by observing their morphological characteristics, gram staining, biochemical tests, and serotyping using Analytical Profile Index Kits. The identified bacteria species were inoculated in conical flasks that contained distilled water, inorganic nutrients and disks prepared from disposable plastic cups and polythene bags to elucidate their degradation potential. Degradation potential of the bacteria was determined by calculating the percentage weight loss of the disposable plastic cups and polythene bags disks after 90 days. Twenty one different species of bacteria were identified. The following bacteria were found to be effective in degradation of disposable plastic cups and polythene bags respectively; Sphingomonas paucimobilis (17.5%, 37.5%), Streptococcus pyogenes (11.5%, 27.0%,), Tatumela ptyseas (11.0%, 21.5%), Bacillus anthracoides (6.0%,7.5%), Chryseobacterium indologenes (3%,7.5%), Chryseobacterium meningosepticum (8%,19.5%), Pseudomonas cepacia (9.5%, 35.5%), proteus penneri (4.5%, 18%), Moraxela sp.(6.5%,19%), Alcaligene sp.(0.5%,27%), Providencia stuarti(1.5%,5.5%) and Providencia rettgeri (5.0%,13.5%). In this study, novel bacteria included Tatumella ptyseas, Proteus penneri and Providencia stuarti. These bacteria are recommended in the degradation of disposable plastic cups and polythene bags.

Key Words: Bacteria, Degradation, Disposable Plastic, Polythene

INTRODUCTION

The elimination of a wide range of pollutants from the environment is a requirement to promote sustainable development of the society with low negative environmental impact. Biological processes play a major role in the removal of contaminants due to catabolic versatility of microorganisms to degrade such compounds (Diaz, 2008).

Plastics have been widely used due to their light weight, inertness and low cost. Their disposal especially those used for packaging have become a major environmental concern

due to poor waste management practices. Their accumulation especially in urban areas is a challenge worldwide. Some plastics collect water and become the breeding places of mosquitoes worsening the problem. In addition, they block drainage systems. Moreover, plastics have also been recently recognized as a major threat to marine life. They sometimes cause blockage in fish intestine, birds and marine mammals.

Plastic degradation is a change in the polymer properties such as tensile strength, colour, shape or molecular weight under the influence of biotic and abiotic factors (Faudree, 1991). Degradation is due to the scission of polymer chain via hydrolysis leading to a decrease in the molecular mass of the polymer. Biodegradation of plastics by microorganism and enzymes seems to be the most effective process of bioremediation. There is considerable research interest in the microbial degradation of plastics waste material since microbes are able to degrade most organic and inorganic materials (Shristi *et al.,* 2006).

A plastic material is called biodegradable if all its organic compounds undergo a complete biodegradation process (Iwata *et al.,* 1998). It is also said to be biodegradable if the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae and ultimately the material is converted to water, carbon dioxide and/or methane and a new cell biomass (Suyama *et al.,* 1998). Biodegradation of plastics is a heterogeneous process which involves biotic and abiotic processes (Tokiwa, 1994). In biotic degradation, microorganisms depolymerize polymers by hydrolysis which is a two step process. First enzymes bind to the polymer substrate then subsequently catalyses a hydrolytic cleavage leading to the scission of the polymer chain bonds and hence decrease in the molecular mass of the polymer (Goldberg, 1995). Two categories of enzymes are actively involved in biological degradation of polymers; extracellular and intracellular depolymerases (Doi, 1990; Tokiwa and Calabia, 2004). Certain fungi secrete hydrogen peroxide and a specific enzyme which act slowly initiating degradation on some resistance natural polymers (Brydson, 2010). Microbial exudates other than enzymes can create a micro-environment in which certain polymers become chemically unstable, for example sulfur bacteria produce sulfuric acid from sulfide or sulfur. This results to cracking or to the chemical disintegration of the polymer which is referred to as stress corrosion cracking (Brysdon, 2010).

Abiotic processes also act on the polymer either parallel or as first stage. The non-biotic effects include physical forces such as thermal-polymer degradation and oxidation or scission of the polymer chains by irradiation (photo-degradation) and chemical hydrolysis (Lee, 1996). Physical forces involve embrittlement and microfragmentation**.** Embrittlement process begins when a polymer is disposed off as waste into the environment. It is activated primarily by sunlight. The polymer begins fragmenting into small pieces and the molecular weight of the polymer chain is reduced, thus increasing the microbial accessibility, and eventual bio-digestion. Micro-fragmentation is the further fragmentation of the embrittlement stage into smaller fragments, which then begins the bio-digestion. This micro-fragmentation of the polymer chain promotes the growth of microbial colonies to speed up biodegradation. Bio-digestion is the consumption of the micro-fragmented pieces, by the microbial colonies, resulting in the biodegradable polymer being ultimately consumed (Villeti *et al.,* 2002).

Environmental factors have a crucial influence on the polymer to be degraded, on the microbial population and on the activity of the different microorganisms themselves (Gu *et al.,* 2000). Parameters such as humidity, temperature, pH, salinity, presence or absence of oxygen and the supply of different nutrients have an important effect on the microbial degradation of the polymers. Presence of molecular oxygen is a prerequisite for the degradation of polymers **(**Doi, 1990).

Plastics characteristics such as its molecular weight, type of fuctional groups and substituents present in its structure and additives added to the polymer play an important role in degradation (Artham and Doble, 2008). The molecular weight determines many physical properties of the polymer. The degree of crystallinity is a crucial factor affecting the biodegradability since enzymes mainly attack the amorphous domain of a polymer. The molecules in the amorphous region are loosely packed and this makes its more susceptible to degradation. The crystalline part of the polymer is more resistant than the amorphous region (Iwata *et al.,* 1998). The type of microorganism also affects the biodegradation of polymer (Artham and Doble, 2008).

Saline lakes have microbes which are able to degrade organic and inorganic materials (Williams, 1996). Such microbes have been isolated in some of the saline lakes in Kenya especially lake Bogoria and lake Elementaita (Jones *et al*., 2005; Ma *et al.,* 2004). Studies on bacterial ecology of lake Nakuru have not been well covered although a lot of studies on zooplankton and phytoplankton ecology in Lake Nakuru have been undertaken by Yasindi *et al.,* 2002; Oduor and Schagerl, 2007). The waters of Lake Nakuru may be rich in halophilic bacteria which may be important in bioremediation. There is need to therefore identify novel bacteria from Lake Nakuru which may be able to remediate our environment from plastic pollutants.

MATERIALS AND METHODS

The study site was Lake Nakuru, located in Nakuru County, Kenya, at an altitude of 1,759 m. Its surface area is 40-60 km^2 but is subject to marked fluctuations because the lake level is constantly rising and falling. The average depth is 1 m (Kairu, 1991) and the length of shoreline is 27 km (Figure 1).

Five sites were selected and geo-referenced using Geographical Positioning System (GPS): Middle lake (latitude -0.354781, longitude 36.093118) hippo point (latitude -0.319546, longitude 36.), Nderit (latitude -0.386313, longitude 36.110497) Makalia (latitude -0.391499, longitude 36.083254l) and Njoro ((latitude -0.331833, longitude 36.092667). These sampling points reflected different catchments areas (Figure 1).

Sampling was done randomly from a boat in the five sites on a monthly basis for six months consecutively from December 2010 to May 2011. At each sampling, triplicate water samples were collected using sterile plastic bottles of 500 ml each. In each case, the samples were collected from ten centimeters (10 cm) beneath the water surface. The samples were kept in a cool box under ice at $4^{\circ}C$ during transportation. These samples were used for serial dilution and culturing of the bacteria. Serial dilution was carried out to make a dilution of up to 10^6. 1ml of the diluted sample water was inoculated on sterile Nutrient agar media using spread plate method. The media was sterilized by autoclaving at 121ºC for 15 minutes. The inoculated plates were incubated upside down at $35^{\circ}C$ for 24 hours. This was done to prevent condensation droplets from falling onto the surface of the agar. The petri dishes were sealed using parafilm to prevent contamination. Sub-culturing was done by streak method. Single colonies were picked using a sterile wire loop and streaked on sterile media to obtain pure cultures.

The isolated bacteria were identified based on physical characterization and biochemical tests using Bergey's manual of determinative bacteriology (Holt, 1994). The bacteria were further identified by serotyping using Analytical Profile Index (API) kit. The API kits used were enteric (API 20E) non-enteric (API 20NE) and Streptococcus kits (API 20strep.) (Biomerieux Inc. USA).

Degradation of Disposable Plastics Cups

Degradation of disposable plastic cups was determined by percentage weight loss of the materials, as described by Kathiresan (2003). The experiment was set up in four replicates. Disks of 0.6 cm diameter were prepared from clear polythene bags and white disposable plastic cups. Ten milligrams (10 mg) of each type of disk was put in a conical flask, 150 ml of distilled water and inorganic nutrients

composed of 0.01 M ammonium phosphate, 0.002 M magnesium sulfate, 0.012 M potassium phosphate and 0.144 M non-iodinated sodium chloride were added to the conical flasks, sealed using alluminium foil and sterilized by autoclaving at 121° C for 20 minutes. The contents in the conical flasks were inoculated with different bacterial species separately after cooling to 25° C. The conical flasks were covered with parafilm to provide aeration, avoid contamination and evaporation.

The negative control contained 10 mg of sterile disks measuring 0.6 cm in diameter, 150 ml of distilled water, and the inorganic nutrients as stated above. A positive control contained 150 ml of distilled water, 5 g of soil from mangrove forest collected at Mtwapa, Kenya, and the inorganic nutrients. This soil was collected at a depth of 5 cm, placed in sterile polythene bags and taken to the laboratory for the purpose of the culturing, isolation and identification of the bacteria present. The soil was autoclaved after bacteria isolation and later inoculated with these bacteria. These were put in conical flasks which were covered using parafilm.

The experimental set up was put in a shaker set at seventy revolutions per minute and at room temperature for 90 days. After 90 days of shaking, the plastic and polythene disks were washed thoroughly using distilled water, shade dried and then weighed for the final weight.

The weight obtained from the plastics degradation experiments were averaged for each bacterium species for the ninety days. The average weight loss caused by each bacterium was computed for both plastic and polythene bags

The degradation was then determined as percentage weight loss and calculated as:

$$\text{Degradation} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

RESULTS

The study revealed that the waters of Lake Nakuru are a good source of bacteria capable of degrading disposable plastics cups and polythene bags. The degradation results of the white disposable plastic cups experiment are summarized in Table 1 below. The bacteria from mangrove soil (positive control) had the highest percentage of plastic degradation with the plastic discs loosing 27.5% of the original weight (Table 1). These bacteria which were isolated from the mangrove soil included *Bacillus sp., Micrococcus sp., Staphylococcus sp.*, and *Streptococcus sp.* The microorganism that caused the highest percentage of degradation from Lake Nakuru was *Sphingomonas paucimobilis* with a percentage of 17.5%. *Providencia stuarti* and *Alcaligen sp.* were slow degraders. *Yersinia pseudotuberculosis* and *Acinetobacter* species were unable to degrade plastics.

The results for the microbial degradation of polythene bags are presented in Table 2. The bacteria from the mangrove soil had the highest percentage (50.5%) of degradation effect on studied polythene bags. These bacteria were *Bacillus sp., Micrococcus sp., Staphylococcus sp.* and *Streptococcus sp.* Among the bacteria isolated from Lake Nakuru, *Sphingomonas paucimobilis* presented the highest percentage of polythene bags degradation (37.5%). *Erwinia amylovora* and *Acinetobacter sp.* were slow degraders as they had only degraded (1%) of polythene bags in 90 days. *Yersinia pseudotuberculosis* and *Morganella morganii* bacteria had no detectable degradation (0%) of the polythene bags after the 90 days of the experiment.

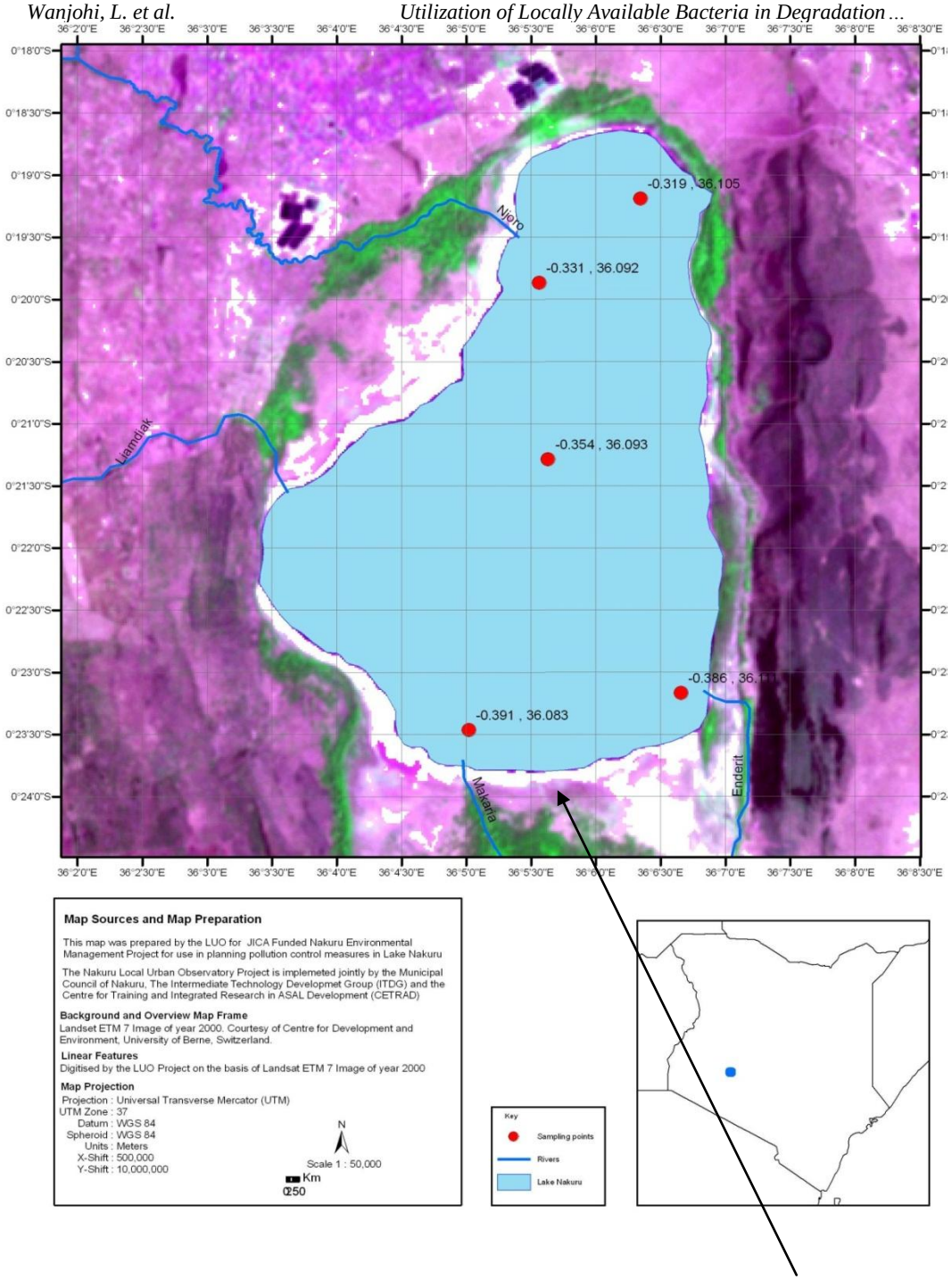

Figure 1: (a) Map of Lake Nakuru Showing the Sampling Points and (b) Map of Kenya Showing the Location of Lake Nakuru

Table 1. Mean Weight (mg) and Percentage Weight Loss of White Disposable Plastic Cups after Treatment with Different Species of Bacteria Isolated from Lake Nakuru

Name of bacteria species	Mean weight(mg)±SE after 90 days of degradation	Weight loss (mg) after 90 days	Percentage weight loss	percentage weight loss attributed to bacteria
Bacillus anthracoides	5.75 ± 0.00	4.25	42.50	6.00
Yersinia pseudotuberculosis	6.35 ± 0.00	3.65	36.50	0.00
Providencia rettgeri	5.85 ± 0.00	4.15	41.50	5.00
Positive control	3.60 ± 0.01	6.40	64.00	27.50
Providencia stuarti	6.20 ± 0.00	3.80	38.00	1.50
Morganella morganii	6.15 ± 0.00	3.85	38.50	2.00
Sphingomonas paucimobilis	4.60 ± 0.01	5.40	54.00	17.50
Acinetobacter sp.	6.35 ± 0.00	3.65	36.50	0.00
Moraxella sp.	5.70 ± 0.00	4.30	43.00	6.50
Erwinia amylovora	5.65 ± 0.00	4.35	43.50	7.00
Negative control	6.35 ± 0.00	3.65	36.50	0.00
Alcaligen spp.	6.30 ± 0.01	3.70	37.00	0.50
Proteus penneri	5.90 ± 0.01	4.10	41.00	4.50
Chryseobacterium meningosepticum	5.55 ± 0.00	4.45	44.50	8.00
Pseudomonas cepacia	5.40 ± 0.00	4.60	46.00	9.50
Erwinia nigrifluens	5.10 ± 0.00	4.90	49.00	12.50
Tatumella ptyseas	5.25 ± 0.00	4.75	47.50	11.00
Chryseobacterium indologenes	6.05 ± 0.00	3.95	39.50	3.00
Streptococcus pyogenes	5.20 ± 0.00	4.80	48.00	11.50

Table 2. Mean Weight (mg) and Percentage Weight Loss of Polythene Paper Bags after 90 Days of Treatment with Different Species of Bacteria Isolated from Lake Nakuru

Name of bacteria species	Mean weight(mg)±SE after 90 days of degradation	Weight loss (mg) after 90 days	Percentage weight loss	Percentage weight loss attributed to bacteria
Baccilus anthracoides	8.40 ± 0.00	1.60	16.00	7.50
Yersinia pseudotuberculosis	9.15 ± 0.00	0.85	8.50	0.00
Providencia rettgeri	7.80 ± 0.01	2.20	22.00	13.50
Positive control	4.10 ± 0.00	5.90	59.00	50.50
Providencia stuarti	8.60 ± 0.00	1.40	14.00	5.50
Morganella morganii	9.15 ± 0.00	0.85	8.50	0.00
Sphingomanas paucimobilis	5.40 ± 0.00	4.60	46.00	37.50
Acinetobacter sp.	9.05 ± 0.00	0.95	9.50	1.00
Moraxella sp.	7.25 ± 0.01	2.75	27.50	19.00
Erwinia amylovora	9.05 ± 0.00	0.95	9.50	1.00
Negative control	9.15 ± 0.00	0.85	8.50	0.00
Alcaligen spp.	6.45 ± 0.00	3.55	35.50	27.00
Proteus penneri	7.35 ± 0.00	2.65	26.50	18.00
Chryseobacterium meningosepticum	7.20 ± 0.00	2.80	28.00	19.50
Pseudomonas cepacia	5.60 ± 0.00	4.40	44.00	35.50
Erwinia nigrifluens	8.00 ± 0.00	2.00	20.00	11.50
Tatumella ptyseas	7.00 ± 0.02	3.00	30.00	21.50
Chryseobacterium indologenes	8.40 ± 0.01	1.60	16.00	7.50
Streptococcus pyogenes	6.45 ± 0.01	3.55	35.50	27.00

Burkhoderia cepacia was able to degrade disposable plastic cup disks (9.5%) and polythene bags (35.5%). This bacterium is found in water and soil and can survive for

prolonged periods in moist environments hence easy to isolate and culture for remediation purpose. *Moraxella sp.* was able to degrade disposable plastic cup disks (6.50%) and polythene bags (19.0%). Kathiresan, (*2003*) reported that *Moraxella sp*. was able to degrade 7.75% of polythene bags and 8.16% of plastic disks per month. *Proteus penneri, Chryseobacterium meningosepticum* and *pseudomonas cepacia* were also good in degradation of both disposable plastics cup disks and polythene bags. *Pseudomonas cepacia* degraded plastic disks (9.50%) and polythene disks (35.50%). Kathiresan, (2003) reported that *pseudomonas sp*. degraded polythene at 20.54% and plastics at 8.16% per month. It is typically found in water and soil hence easy to isolate and culture for remediation purposes.

Most bacteria were able to degrade polythene paper bags at a higher percentage than plastics cups disks (Figure 2). *Morganella morganii* degraded plastics cups though to a smaller degree but was unable to degrade polythene bags (Figure 2). *Yersinia pseudotuberculosis* was unable to degrade both plastics cups and polythene bags. *Sphingomonas paucimobilis, Erwinia nigrifluence, Tatumella ptyseas* and *Streptococcus pyogenes* showed high rates of degradation of both plastics cups and polythene bags (Figure 2). *Acinetobacter sp*. was able to degrade polythene bags but unable to degrade plastics cups in 90 days (Figure 2).

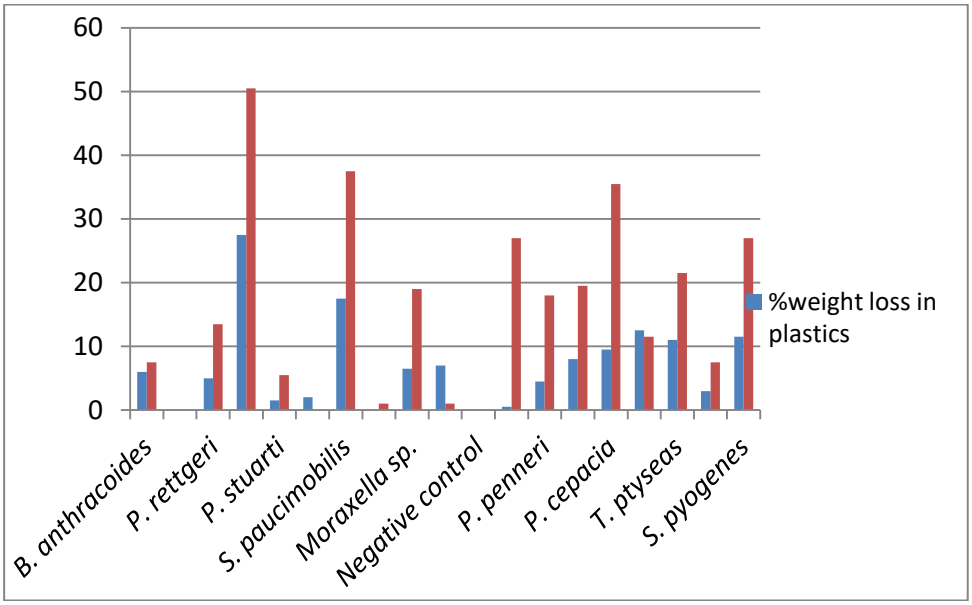

Figure 2. Comparison of the Percentage Weight Loss in Plastic Cups and Polythene Bags by each Bacterium Species Isolated from Lake Nakuru

DISCUSSION

Bacteria species isolated from Lake Nakuru were able to biodegrade disposable plastic cups and polythene bags. The biodegradation might have been through enzymatic action, leading to a significant change in the weight of the disposable plastic cups and polythyne bags disks. The major mechanisms involved in this degradation are; the adherence of the microorganism on the surface of the plastic followed by colonization of the exposed surface. Due to properties and the size of the

polymer molecules, microbes are unable to transport the polymeric material directly into the cells where most biochemical processes take place. They first excrete extracellular enzymes which depolymerize the polymers outside the cells. This yields smaller molecules of short chains, for example oligomers, dimers, and monomers that are able to pass semi-permeable outer bacterial membrane and be utilised as carbon and energy sources (Frazer, 1994). Consequently this reduces the molar mass of the polymers to generate water soluble intermediates which are transported into the microorganism and fed into the appropriate metabolic pathways (Barzal *et al.,* 1989). As a result the end products of these metabolic processes include water, carbon dioxide or methane and a new cell biomass (Suyama *et al.,* 1998).

The type of microorganism affects the biodegradation of polymer (Artham and Doble, 2008). Different species of bacteria have different abilities to degrade plastics and polythene bags. Hence there were different rates of degradation of both plastics and polythene depending on the species of the bacteria present. Different bacteria species were able to degrade plastic and polythene at different rates although they had received the same amount and type of nutrients. *Sphingomonas paucimobilis* had the highest percentage of degradation. Other microorganisms that were good in degradation of both plastic and polythene disks were *Streptococcus pyogenes, Tatumella ptyseas, Pseudomonas cepacia, Erwinia nigrifluence, Chryseobacterium meningosepticum* and *Moraxella sp. Sphingomonas paucimobilis* can be used in bioremediation and biodegradation. *S. paucimobilis* occurs in various environments hence easy to isolate and culture for remediation purpose. *S. paucimobilis* is metabolically versatile, hence can utilize a wide range of naturally occurring compounds and environmental contaminants. Burd, (2009) discovered that Sphingomonas can degrade over 40% of the weight of polythene in less than three months (http://www.mnn.com/green-tech/research-innovations). According to Ni'matuzahroh *et al.* (1999), Sphingomonads have been utilised for a wide range of biotechnological applications, from bioremediation of environmental contaminants to production of extracellular polymers such as sphingans which are used extensively in the food and other industries due to their biodegradative and biosynthetic capabilities. One strain, Sphingomonas sp. 2MPII, can degrade 2-methylphenanthrene.

The molecular weight determines many physical properties of the polymer. Generally, increase in molecular weight of the polymer decreases its degradability by microorganism (Gu *et al*., 2000; Yutaka 2009). This is because high molecular weight results in a sharp decrease in solubility making them unfavourable for microbial attack. The reason is that bacteria assimilates the substrate through the cellular membrane and then further degrade it by cellular enzymes (Gu *et al.,* 2000). In this study, most of the bacteria were able to degrade polythene paper bags at a higher rate compared to disposable plastic cups. This may be due to the molecular weight of plastic which is higher than that of the polythene. Also plastics are thicker than polythene. In this research, this contributed to the higher weight loss of the polythene than that of plastic for each bacteria species. The weight loss of polythene was higher than that of plastics for each bacteria species except for *Erwinia spp.* and *Morganella morganii*. *Erwinia spp*. had a higher weight loss of plastics than polythene while *Morganella morganii* was unable to degrade polythene. These bacteria could be having enzymes that are more specific to the degradation of the compounds found in the plastic cups. Some of the bacteria that were able to degrade polythene at a higher percentage than plastics include *S. paucimobilis*, *P. retigeri, P. cepacia, Alcaligen sp* and *Streptococcus pyogenes.* These findings were in agreement with the findings of Kathiresan (2003) who reported that *Streptococcus sp.* was able to degrade polythene at 2.19% and 1.07% of plastics per month.

The surface area of the material being degraded that is exposed to the bacteria affects the percentage of degradation. The more the surface area exposed to the bacteria, the higher the rate of degradation (Goldberg, 1995). The higher rate of degradation by bacteria on the polythene bags may be attributed to the surface area exposed to the bacteria. The surface area of the plastic exposed to the bacteria species in this study was smaller compared to the surface area of polythene papers. More polythene discs were put in the experiment set up than the number of plastic discs to achieve the same mass. Hence more surface area of polythene was exposed to the bacteria than that of plastics leading to a higher percentage of degradation of polythene disks than that of plastic cups disks. *Acinetobater sp*. was able to degrade polythene (1%) but unable to degrade plastics. This may be attributed to the thickness of plastics that was higher than that of the polythene and also to the surface area of polythene exposed to the bacteria compared to the plastics. This species is metabolically versatile and hence can be exploited in various biotechnological applications including biodegradation and bioremediation (Gutnik, 2008). Gerischer (2008) reported that many of the characteristics of *Acinetobacter sp.* point to the possibility of exploiting its unique features for future applications.

The initial breakdown of a polymer can result from a variety of physical, chemical and biological forces with chemical hydrolysis being the most important (Goldberg, 1995). These leads to reduction of molecular weight of the polymer and hence increase in the microbial accessibility (Ghazali, 2004). In this study, initial reduction of molecular weight is attributed to the physical and chemical forces which were activated by heat generated during shaking. The molecular weight reduction may have been as a result of carboxyl group oxidation (Faudree, 1991). In the plastic experiment 36.5% weight reductions occurred in the negative control. This may be attributed to physical and chemical forces (Faudree, 1991). In the polythene experiment, 8.5% weight reduction occurred in the negative control. This is attributed to the physical and chemical forces of degradation (Goldberg, 1995).

CONCLUSION

In conclusion, the bacteria from Lake Nakuru can be used to eliminate disposable plastic cups and polythene paper bags through biodegradation and hence leading to clean environment and soil's nutrient replenishment. The processing of waste degradation using living organisms is environmentally friendly, relatively simple, and cost effective.

RECOMMENDATION

Further study on bacterial enzymes or organic acids that may be involved in degradation of the polythene and plastics need to be studied. This will pave way for finding technology for degrading the plastic and polythene materials, which are otherwise hazardous to environment.

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REFERENCES

Artham, T. and Doble, M. (2008). Biodegradation of Aliphatic and Aromatic Polycarbonates. *Macromol Biosci* 1.

Barlaz, M. A., Ham, R. K and Schaefer, D. M. (1989). Mass-balance analysis of anaerobically decomposed refuse. *J. of Environ. Eng.*; 115:1088–102.

Diaz, E. (2008). Microbial Biodegradation: Genomics and Molecular Biology, 1st ed., Caister Academic Press.

Doi, Y. (1990). Microbial Polyesters. New York:" VCH Publishers;

Faudree, M. C. (1991). Relationship of Graphite/Polyimide Composites to Galvanic Processes" Society for the Advancement of Material and Process Engineering *(SAMPE)* 2: 1288–1301.

Frazer, A. C. (1994). Methylation and other transformations of aromatic compounds by

acetogenicbacteria. In: Drake HL, editor. Acetogenesis. New York: Chapman & Hall; p. 445–83.

Gerischer, U. (2008). Acinetobacter Molecular Biology (1st ed.). Caister Academic Press. ISBN 978-1-904455-20-2.. (2008).

Ghazali, F. M., Rahman, R. N. Salleh, A. B. and Basri, M. (2004). Int. Biodeterior. Biodegradation.

Goldberg, D. (1995). A review of the biodegradability and utility of poly (caprolactone) J. Environ. Polym. Degrad. (1995) 3:61–8.

Gu, J. D., Ford, T. E., Mitton, D. B. and Mitchell, R. (2000). Microbial degradation and deterioration of polymeric materials In: Revie W, editor. The Uhlig Corrosion Handbook. 2nd Edition. New York: Wiley; (2000) p. 439–60.

Gutnick, D. (2008). Potential Application of Acinetobacter in Biotechnology, *Acinetobacter Molecular Biology* (Gerischer U, ed.). *Caister Academic Press. ISBN 978-1-904455-20-2.* .

Holt, J. G. (1994). Bergey's Manual of Determinative Bacteriology. http://www.mnn.com/green-tech/research-innovations/blogs/boy-discovers-microbe-that-eats-plastic. Date of access 15 September 2010 8.30 am

Iwata, T. and Doi, Y. (1998). Morphology and enzymatic degradation of poly(L-lactic acid) single crystals"*Macromolecules 31 :* 2461-2467.

Jones, B. E., Grant, W. D., Duckworth, A. W., Schumann, P., Weiss, N. and Stackebrandt, (2005). E. *Cellulomonas bogoriensis sp. nov*., an alkaliphilic *cellulomonad*. *Int. J. Syst Evol. Microbiol*. 55: 1711–1714

Kairu, J. (1991). Studies of the Concentration of Organic Chlorine Pesticides and Metal Residues in Fish and Birds of Lake Nakuru, Kenya. MSc. Thesis Agricultural University, Norway.

Kathiresan, K. (2003). Polythene and plastic degrading microbes from the mangrove soil. International journal of tropical biology and conservation.

Lee, S. Y. (1996). Bacterial Polyhydroxyalkanoates. *Biotechnol. Bioeng*. 49: 1-1

Ma, Y., Xue, Y., Grant, W. D., Collins, N. C., Duckworth, A. W., van Steenbergen, R. P. and Jones, B.E. (2004). *Alkalimonas amylolytica* gen. nov. sp and *Alkalimonas delamerensis* gen. nov sp. nov., novel alkaliphilic bacteria from soda Lakes in China and East Africa." *Extremophiles.*. 8:193-200.

Ni'matuzahroh, G., Gilewicz, M., Guiliano, M. and Bertrand, J. (1999). In-Vitro Study of Interaction between Photooxidation and Biodegradation of 2-Methylphenanthrene By *Sphingomonas* Sp 2MPII". *Chemosphere* 38 (11): 2501–2507.

Oduor, S. O. and Schagerl, M. (2007). Temporal trends of ion contents and nutrients in three Kenyan Rift Valley saline-alkaline Lakes and their influence on phytoplankton biomass. *Hydrobiologia* 585:59

Shristi, K., Hather, A. A. M. and Christi, K. S. (2006). Diversity and effectiveness of tropical mangrove soil microflora on the degradation of polyethylene carry bags. India.

Suyama, T., Hosoya, H., and Tokiwa, Y., "Bacterial Isolates Degrading Aliphatic Polycarbonates." *FEMS Microbiol.* (1998), 161,255-261.

Tokiwa, Y. and Calabia, B. P. (2004) Degradation of microbial polyesters. Biotechnol Lett 26:1181–9.

Tokiwa, Y., Iwamoto, A., Doi, Y., Fukuda, K., (1994). Biodegradable Plastics and Polymers. Amsterdam: Elsevier Science; p. 190–198.

Villeti, M. A., Crespo, J. S., Soldi, M. S., Pires, A. T. N., Borsali, R., and Soldi, V., (2002), Thermal degradation of natural polymers. *J. thermal analysis and calorimetry* v. 67: 295-303.

Williams, W. D. (1996). The largest, highest and lowest Lakes of the world: Saline Lakes. Peter Kilham Memorial Lecture, Sao Paulo, 1995. Verh. Internat. Verein. Limnol.

Yasindi, A. W., Lynn, D. H. and Taylor, W. D. (2002). Ciliated protozoa in Lake Nakuru, a shallow alkaline-saline Lake in Kenya: Seasonal variation, potential production and role in the foodweb. *Archive of fur Hydrobiologia.* 154 (2): 311-325.

Yutaka, T., Buenaventurads, P., Calabia, U., Ugwu C., and Selichi, A. (2009). Biodegradability of plastics. Inter. J. mole. sci. V.10: 3722-3742.