Scientific Research Publishing

Advances in Microbiology, 2017, 7, 653-665
http://www.scirp.org/journal/aim
ISSN Online: 2165-3410
ISSN Print: 2165-3402

Antimicrobial Resistance Encountered in Garbage Collection Areas and Dumpsites in Nairobi, Kenya Using *Escherichia coli* and *Klebsiella* as Indicator Species

Grace Waturu[1], Winnie Mutai[1], John Kiiru[2], Moses Musyoki[1], Leonard Ochieng[3]

[1]Department of Medical Microbiology, School of Medicine, University of Nairobi, Nairobi, Kenya
[2]Centre of Microbiology Research, Kenya Medical Research Institute, Nairobi, Kenya
[3]Obstetrics and Gynecology Department, School of Medicine, University of Nairobi, Nairobi, Kenya
Email: waturug@yahoo.com

How to cite this paper: Waturu, G., Mutai, W., Kiiru, J., Musyoki, M. and Ochieng, L. (2017) Antimicrobial Resistance Encountered in Garbage Collection Areas and Dumpsites in Nairobi, Kenya Using *Escherichia coli* and *Klebsiella* as Indicator Species. *Advances in Microbiology*, **7**, 653-665.
https://doi.org/10.4236/aim.2017.79051

Received: August 3, 2017
Accepted: September 3, 2017
Published: September 6, 2017

Abstract

Dumpsites and garbage collection areas can act as reservoirs of highly resistant bacterial strains and facilitate the dissemination of Multidrug resistant strains to those living and work on or near the dumpsites and garbage collection areas. The objective of this study was to determine the potential of garbage collection areas and dumpsites in different parts of Nairobi as possible sources of resistant strains using *E. coli* and *Klebsiella* as indicator species. The study design was a cross-sectional survey. Sample collection was carried out at different days in seventeen different areas. A total of 126 samples were collected during the sampling period. The samples were then transported to the laboratory for analysis. The samples were cultured on MacConkey agar. Gram staining was done on discrete isolates based on colony characteristics. Biochemical tests were performed on colonies from primary cultures for final identification of the isolates. Antimicrobial disc susceptibility tests and pathogenicity tests were also carried out on the indicator isolates. A total of 121 *E. coli* and 165 *Klebsiella* were isolated from all the sampled sites. The highest bacterial burden was recorded from Muthurwa estate dumpsite, with a mean viable count of 8.2×10^{10} cfu/gm while the least was from Dandora dumpsite with a mean count of 1.1×10^{11} cfu/gm. Overall, gentamicin was the most effective antibacterial agent on *Klebsiella* and meropenem was the most effective on both *E.coli* and *Klebsiella* strains. The isolates showed high resistance to ampicillin, streptomycin, and trimethoprim-sulfamethoxazole. It is concluded that municipal waste dumpsites and garbage collection areas bear heavy burdens of potentially resistant bacteria which may constitute major

public health hazards, not only to the immediate communities but also to the families of such site workers.

Keywords

Dumpsite, Garbage Collection Area, Indicator Organisms, Antimicrobial Resistance

1. Introduction

The misuse of antimicrobial agents has been identified as one of the major forces resulting in the rapid spread of resistance, but the nature of this relationship is complex. Resistance to antimicrobials is sometimes brought about by a change in the bacterial genome, which can occur by the transfer of antimicrobial resistance genes which may be found in some of the bacteria found in the environment and transferred to those without the resistance genes and also through other horizontal gene transfer elements [1]. Products that are used in disinfection and sterilization, as well as heavy metals used in industries and households along with antibiotics, creating selective pressure in the environment that lead to mutations in microorganisms [2].

Indiscriminate waste dumping enhances the breeding of microorganisms that pose a danger to the human population. Urban wastes contain a wide range of things that may have come from different sources e.g. hospitals, animal sheds and may carry antimicrobial resistance bacteria belonging to the human and animal commensal flora, mainly Enterobacteriaceae [3]. Waste degradation is enhanced by the presence of soil microorganisms that create a conducive environment for the resistant bacteria e.g. *Salmonella* species and *E. coli* to thrive in thus becoming potential human pathogens and may cause severe health hazards [4]. The presence of rodents in these dumpsites and garbage collection areas enhance the spread of antimicrobial resistant bacteria to other areas. Previous studies have focused on the identification of these disease vectors on dumpsites and have reported cockroach, housefly, black garbage fly, and stable fly to be the most prevalent disease vectors on the dumpsites and garbage collection areas [5] [6].

Enterobacteriaceae are one of the major causes of infections and deaths around the world. The prevalence of antimicrobial resistance in this family of bacteria e.g. *Escherichia coli*, *Salmonella* and *Shigella* has raised over the years. One of the major reasons for the increase is the spread of *Klebsiella pneumoniae* carbapenemase (KPC), a class A serine carbapenemase that was originally isolated from *Klebsiella pneumoniae* in 1996 [7].

Resistance in pathogenic organisms poses a distinct clinical challenge. However commensal bacteria may enhance the spread of resistant bacteria as they may act as reservoirs of the resistance genes which may have been acquired through various horizontal gene transfer elements. This, therefore, increases the carriage le-

vels of resistant organisms. The resistant microorganisms from clinical samples may gain their entry into the environment through fecal contamination and various wastes from the hospital that has not been sterilized properly. *Escherichia coli* and *Klebsiella* species were used in this study as an indicator species as they are commonly associated with humans and animals disease and have also been used in other studies to gauge the spread of acquired resistance [8].

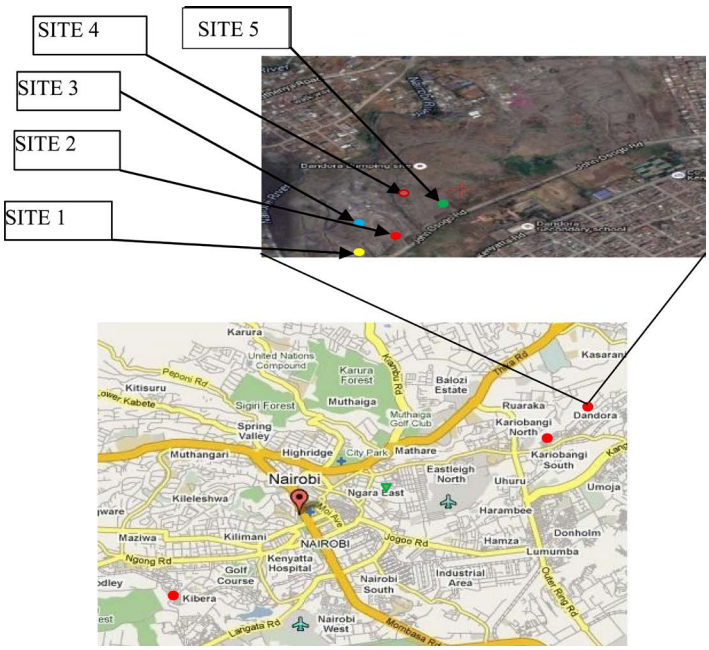
2. Materials and Methods

2.1. Study Area

Dumpsites near schools, residential areas and the municipal general waste dumping sites in Nairobi area were selected for the study and sampled. In order to verify the most accessed area of these dumpsites and garbage collection areas by the street families and other people relying on dumpsites for a living, a qualitative survey of the dumpsites and garbage collection areas was conducted. The purpose of the survey was to determine the most appropriate area to sample for the main study. This was done by visiting the dumpsites and garbage collection areas before the start of the study and surveying the areas and identifying potential barriers to our study.

2.2. Sampling Points

A total of 17 dumpsites (permanent dumping area) and garbage collection areas (temporary dumping area where garbage is dumped awaiting collection) were randomly sampled in different parts of Nairobi area (**Figure 1**).



Key: ● -Dumpsites and garbage Collection areas near residential places; ✦ -Dumpsites and garbage Collection areas in Market areas; ▲ -Dumpsites and garbage Collection areas near Schools.

Figure 1. Aerial view of sampling sites in Dandora sampling area.

2.3. Sample Collection

Sample collection was randomly carried out in different days in seventeen different points. A total of 126 samples were collected during the sampling period. At each sampling station, the sub-surface soil, mixed solids, leaking water, stagnant water, swabs and food samples were collected from one squire foot area into sterile sampling bottles and appropriately labeled. Six samples were collected from each site. The samples were then transported to the laboratory for analysis.

2.4. Determination of Microbial Load in the Dumpsites and Garbage Collection Areas

One gram (1 g) of each solid samples and 1 mL of the liquid samples and swabs were suspended in 10 mL physiological sterile saline. Serial dilutions of 10 fold, 5 fold, and 1 fold dilutions were prepared from the 10 mL suspension and transferred onto duplicate molten Plate Count Agar (PCA) mixed and allowed to cool at room temperature. This was then incubated at 37˚C for 24 hours. Colonies were determined from duplicate plates and the average counts recorded as mean viable bacteria (colony forming units [CFUs] of the sample. The low and high CFUs were reached by dividing the dumpsites and garbage collection areas into two, those that had CFUs above 5.0 were considered to be high and those below 5.0 considered being low.

2.5. Isolation and Identification of *E. coli* and *Klebsiella* Species

A loop full (1 µl) of the mixture incubated in buffered peptone water was then transferred onto MacConkey agar plates and incubated at 37˚C for 24 hours for isolation of *E. coli* and *Klebsiella* species. After overnight incubation the plates were then examined for growth and presumptive identification of *E. coli* and *Klebsiella* species for lactose-fermenting colonies (pink). Presence of pink non-mucoid colonies for *E. coli* and pink mucoid for *Klebsiella* species were further identified by biochemical tests.

2.6. Biochemical Identification of the Isolates

Pure discrete colonies of *E. coli* and *Klebsiella* species from primary cultures were identified by gram staining and biochemical tests. Colonies that appeared as gram negative rods were tested for indole test, methyl-red test, Voges-Proskauer test and citrate utilization (IMViC). Presence of *E. coli* was interpreted as a positive reaction for indole and methyl-red tests and a negative reaction for Voges-Proskauer test and lack of citrate utilization. Additionally presence of *Klebsiella* species was interpreted as a negative reaction for indole and methyl-red tests and a positive reaction for Voges-Proskauer test and citrate utilization [9].

2.7. Antimicrobial Susceptibility Testing

The antimicrobial susceptibility testing was done on 286 isolates on Mueller-

Hinton agar plates (Oxoid). The isolates were tested against the following antibiotics; Ampicillin (10 µg), Cefpodoxime (10 µg), Ceftazidime (30 µg), Cefoxitin (30 µg) Cefepime (30 µg), Amoxicillin-Clavulanic acid (10/100µg ratio), Ciprofloxacin (10 µg), Tetracycline (30 µg), Trimethoprim Sulfamethoxazole (30 µg), Gentamicin (10 µg), Chloramphenicol (30 µg), Streptomycin (25 µg), Nalidixic acid (10 µg), and Meropenem (10 µg). The plates were then incubated at 37˚C for 18 - 24 hours. The inoculums for susceptibility testing were compared against the McFarland 0.5 turbidity standards with *E.coli* ATCC 25,922 strain being used as the control standard for quality assurance of media and the antimicrobial discs. The interpretation of results was according to Clinical and Laboratory Standards Institute guidelines [10].

3. Results

3.1. Contamination Levels of the Dumpsites and Garbage Collection Areas

The lowest CFU from any given sampling point was 1.1×10^{11} that was recorded in Dandora dumpsite. The site with the highest CFU value was Muthurwa estate dumpsite that recorded 8.2×10^{10}. Other sites with high CFU counts were Umama garbage collection area (Komarock), Kawangware market dumpsite, Kenyatta staff quarter garbage collection area, Kweria garbage collection area, City market garbage collection area, Central police garbage collection area, Kibera dumpsite, and Kenyatta market dumpsite while Seven of the dumpsites and garbage collection areas (Ayany dumpsite, Dandora dumpsite, Ngara market garbage collection area, Muthurwa market garbage collection area, Masai market dumpsite, Mareba garbage collection area (Kibera), District Commissioner garbage collection area (Kibera) recorded CFUs below 2.0×10^{10} **Table 1**.

3.2. Antimicrobial Susceptibility Profile of *E. coli* and *Klebsiella* Species

Resistance pattern to all antimicrobials for *E. coli* and *Klebsiella* was above 5% except for ciprofloxacin (3.3% *E.coli*, and 2.4% *Klebsiella*), meropenem (1.7% *E.coli* and 1.8% *Klebsiella*) and gentamicin (3.3% *E.coli* and 0% *Klebsiella*) **Table 2**.

3.3. Antimicrobial Resistance in Dumpsites and Garbage Collection Areas with High and Low Colony Forming Units

In general, resistances frequencies were similar for *E. coli* and *Klebsiella* obtained from samples with high CFUs to those obtained from samples with low CFUs. In the dumpsites and garbage collection areas that had high CFUs, such as Muthurwa estate dumpsite, Central police garbage collection area, City market garbage collection area, City park market dumpsite **Figure 2(a)**, there were high resistance prevalence's of above 25% to streptomycin, ampicillin, tetracycline and trimethoprim sulfamethoxazole for isolates belonging to both species.

In contrast, there was low resistance to meropenem, gentamicin, and ciprofloxacin (≤5%) in both species. The study also found that 42% of *E. coli* isolates were resistant to ampicillin compared to 59% of *Klebsiella* isolates found in this study.

Table 1. Average microbial load of the samples from dumpsites and garbage collection areas and their characteristics.

Dumpsite/garbage collection area	Area in Nairobi	Location	Average CFUs	Category of CFU	Dumpsite/garbage collection area characteristics
Muthurwa estate dumpsite	East	Residential	8.2×10^{10}	High	Fecal contamination, Domestic/Rodents
Umama garbage collection area (Komarock)	North Western	Residential	7.9×10^{10}	High	Seepage, Fecal contamination,
Kawangware market dumpsite	East	Market	7.7×10^{10}	High	Fecal contamination, Domestic/Rodents
Kenyatta staff quarter garbage collection area	South	Market	7.3×10^{10}	High	Seepage, Fecal contamination, Domestic/Rodents, Human activity
Kweria garbage collection area	Central	Residential	7.2×10^{10}	High	Fecal contamination, Domestic/Rodents, Human activity
City market garbage collection area	Central	Market	6.7×10^{10}	High	seepage, Human activity
Central police garbage collection area	West	Residential	6.1×10^{10}	High	Seepage
Kibera dumpsite	South	Residential	5.0×10^{10}	High	Seepage, Fecal contamination, Domestic/Rodents, Human activity
Kenyatta market dumpsite	South	Residential	5.0×10^{10}	High	Seepage, Fecal contamination, Domestic/Rodents, Human activity
City park market dumpsite	South Western	Market	2.0×10^{10}	High	Seepage, Domestic/Rodents, Human activity
Muthurwa market garbage collection area	East	Residential	1.8×10^{11}	Low	Fecal contamination, Human activity
Mareba garbage collection area (Kibera)	South Eastern	School	1.5×10^{11}	Low	Fecal contamination, Domestic/Rodents, Human activity
Ayany dumpsite	South Eastern	Residential	1.5×10^{11}	Low	Seepage, Human activity
Ngara market garbage collection area	West	Residential	1.4×10^{11}	Low	Fecal contamination, Domestic/Rodents
Masai market dumpsite	West	Market	1.2×10^{11}	Low	Human activity
District Commissioner garbage collection area (Kibera)	South	Residential	1.2×10^{11}	Low	Seepage, Fecal contamination, Human activity
Dandora dumpsite	North Western	Residential	1.1×10^{11}	Low	Seepage, Fecal contamination, Domestic/Rodents, Human activity

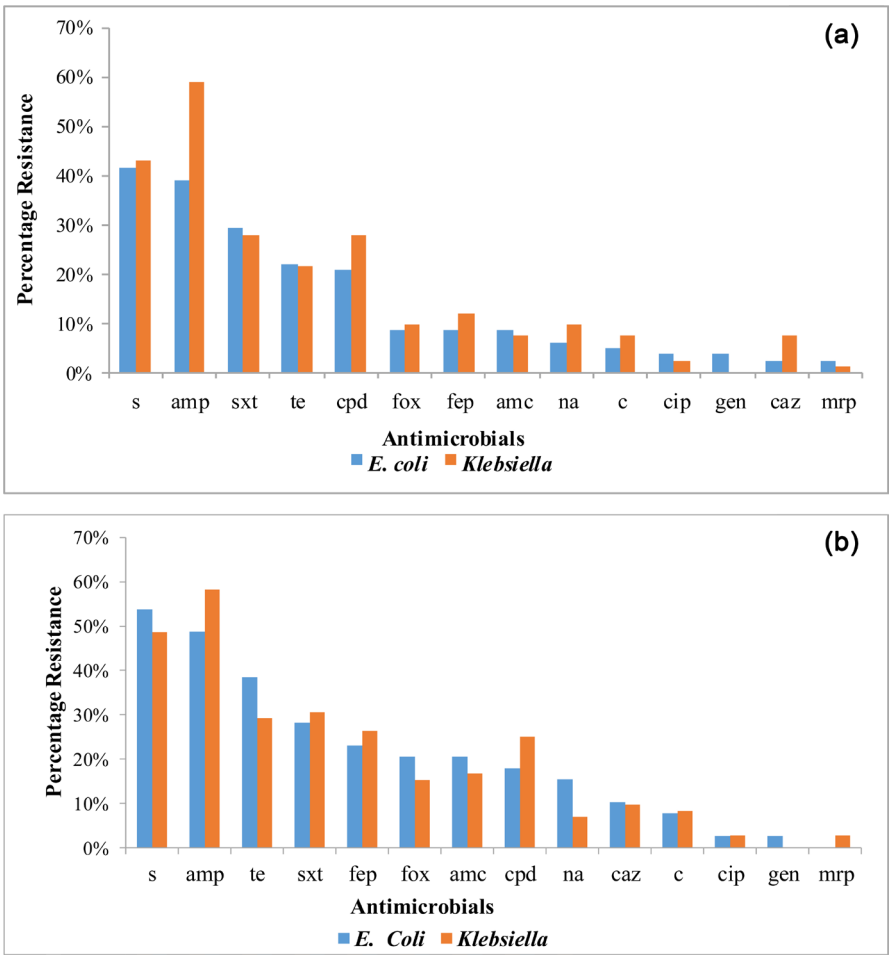
Key: Seepage-leakage of water into the ground in and around the dumpsite or garbage collection area, Fecal contamination—presences of feces on the dumpsite or garbage collection area, Domestic/Rodents—presence of livestock (e.g. goats) or rodents (e.g. rats) on the dumpsite and garbage collection area, Human activity—presence of humans on or adjacent to the dumpsite and garbage collection area.

Table 2. Antibiotic susceptibility pattern of *E. coli* and *Klebsiella* among the antibiotics tested.

Antimicrobial	*E. coli* (%)	*Klebsiella* (%)
Ceftazidime (CAZ)		
Resistance	6 (5.0)	14 (8.5)
Intermediate	0	3 (1.8)
Susceptible	115 (95.0)	148 (89.7)
Cefpodoxime (CPD)		
Resistance	24 (19.8)	44 (26.7)
Intermediate	23 (19.0)	15 (9.1)
Susceptible	74 (61.2)	106 (64.2)
Cefoxitin (FOX)		
Resistance	15 (12.4)	20 (12.1)
Intermediate	2 (1.7)	1 (0.6)
Susceptible	104 (86.0)	144 (87.3)
Cefepime (FEP)		
Resistance	16 (13.2)	30 (18.2)
Intermediate	39 (32.2)	61 (37.0)
Susceptible	66 (54.5)	74 (44.8)
Ciprofloxacin (CIP)		
Resistance	4 (3.3)	4 (2.4)
Intermediate	2 (1.7)	4 (2.4)
Susceptible	115 (95.0)	157 (95.2)
Amoxicilin clavulanic acid (AMC)		
Resistance	15 (12.4)	19 (11.5)
Intermediate	18 (14.9)	18 (10.9)
Susceptible	88 (72.7)	128 (77.6)
Tetracycline (T)		
Resistance	33 (27.3)	41 (24.8)
Intermediate	6 (5.0)	13 (7.9)
Susceptible	82 (67.8)	111 (67.3)
Meropenem (MRP)		
Resistance	2 (1.7)	3 (1.8)
Intermediate	19 (15.7)	51 (30.9)
Susceptible	100 (82.6)	111 (67.3)
Streptomycin (S)		
Resistance	55 (45.5)	75 (45.5)
Intermediate	59 (48.8)	80 (48.5)
Susceptible	7 (5.8)	10 (6.1)
Nalidixic acid (NA)		
Resistance	11 (9.1)	14 (8.5)
Intermediate	0	2 (1.2)
Susceptible	110 (90.9)	149 (90.3)
Cloramphenical (C)		
Resistance	7 (5.8)	13 (7.9)
Intermediate	2 (1.7)	4 (2.4)
Susceptible	112 (92.6)	148 (89.7)

Continued

Gentamicin (GEN)		
Resistance	4 (3.3)	0
Intermediate	3 (2.5)	8 (4.8)
Susceptible	114 (94.2)	157 (95.2)
Trimethoprim sulfamethoxazole (SXT)		
Resistance	35 (28.9)	48 (29.1)
Intermediate	6 (5.0)	0
Susceptible	80 (66.1)	117 (70.9)
Ampicilin (AMP)		
Resistance	51 (42.1)	97 (58.8)
Intermediate	16 (13.2)	16 (9.7)
Susceptible	54 (44.6)	52 (31.5)



Key: AMP-ampicillin (10 µg), CPD-cefpodoxime (10 µg), CAZ-ceftazidime (30 µg), FOX-cefoxitin (30 µg), FEP-cefepime (30 µg), CIP-ciprofloxacin (10 µg), AMC-amoxicillin clavulanic acid (10 µg), TE-tetracycline (30 µg), MRP-meropenem (10 µg), S-streptomycin (10 µg), NA-nalidixic acid (10 µg), C-chloramphenicol (10 µg), GEN-gentamicin (10 µg), SXT-trimethoprim sulfamethoxazole (30 µg).

Figure 2. (a) antimicrobial resistance in dumpsites and garbage collection areas with high Colony Forming Units, (b) -antimicrobial resistance in dumpsites and garbage collection areas with low Colony Forming Units.

Resistance to gentamicin among isolates from sites recording high CFUs was only observed for *E. coli* (6%) while resistance to meropenem from the same population of isolates, was observed in *Klebsiella* (2.8%).

There was high resistance (>20%) to streptomycin, ampicillin, tetracycline, trimethoprim sulfamethoxazole and cefpodoxime for both species in the dumpsites and garbage collection areas that had low CFUs such as the Ngara market garbage collection area, Ayany dumpsite, Dandora dumpsite, Muthurwa market garbage collection area **Figure 2(b)**. In such sites, there was a low resistance of *E. coli* and *Klebsiella* to meropenem, gentamicin, and ciprofloxacin (<5%). The only *E. coli* strains found to be resistant to gentamicin were from the sites with low CFUs.

3.4. Antimicrobial Resistance Profiles

The isolates were classified into three resistance profiles (those that were fully susceptible, those resistant to 1 - 3 antimicrobials and those resistant to more than 3 antimicrobials (MDROs) as shown in **Table 3**. There were no isolates that

Table 3. Distribution of isolates with different resistance profiles across dump sites and garbage collection areas.

Dumpsites/garbage areas	No. of isolates	Number of antimicrobials to which *E. coli* and *Klebsiella* were resistant (%)		
		Fully susceptible	1 - 3 antimicrobials	>3 antimicrobials (MDROs)
Ayany Dumpsite	19	2 (10.5)	10 (52.6)	7 (36.8)
Central police garbage collection area	18	1 (5.6)	12 (66.7)	5 (27.8)
City market garbage collection area	22	3 (13.6)	12 (54.5)	7 (31.8)
City park Market Dumpsite	29	5 (17.2)	20 (69.0)	4 (13.8)
Dandora Dumpsite	33	1 (3.0)	27 (81.8)	5 (15.2)
District Commissioner's garbage collection area (Kibera)	9	0	7 (77.8)	2 (22.2)
Kenyatta Market Dumpsite	15	3 (20.0)	10 (66.7)	2 (13.3)
Kenyatta staff quarter garbage collection area	24	10 (41.7)	13 (54.2)	1 (4.2)
Kibera Dumpsite	15	0	12 (80.0)	3 (20.0)
Kweria garbage collection area	24	3 (12.5)	17 (70.8)	4 (16.7)
Mareba garbage collection area (Kibera)	7	0	4 (57.1)	3 (42.9)
Masai Market dumpsite	14	0	11 (78.6)	3 (21.4)
Muthurwa Estate Dumpsite	12	0	4 (33.3)	8 (66.7)
Muthurwa Market garbage collection area	17	1 (5.9)	10 (58.8)	6 (35.3)
Ngara market garbage collection area	17	3 (17.6)	12 (70.6)	2 (11.8)
Kawangware Market Dumpsite	4	0	4 (100.0)	0
Umama garbage collection area (Komarock)	7	0	2 (28.6)	5 (71.4)

Key: The fully susceptible are those that did not show any resistance while resistance is showing resistance to 1-3 antimicrobials and MDROs are those that show resistance to more than 3 antimicrobials.

were fully susceptible in 7 (41%) of the seventeen dumpsites and garbage collection areas sampled. Most (61%) of the isolates were resistant to 1 - 3 antimicrobials. Another 23% of isolates were resistant to more than 3 antimicrobials and were thus multidrug resistant (MDROs). In the Umama garbage collection area (Komarock) 5 (71%) out of the 7 isolates recovered, were MDROs but no MDROs strain was recovered from the Kawangware market dumpsite. The sites with the highest prevalence of MDROs strains included Muthurwa estate dumpsite (66%) and Umama garbage collection area (Komarock) (71%) that both recorded high CFUs as well as shown earlier in Table 1.

4. Discussion

Based on the qualitative survey, this study showed that there was evidence of human contact with garbage and dumpsites surveyed. Some of these sites had high CFUs indicating a high possibility of contamination with fecal material. It is, therefore, possible that these interactions pose a serious danger to the public who work and sell their salvaged merchandise from such sites. Such merchandise may include fruits and vegetables. This may result in the spread of pathogens to the unsuspecting public. These results are in agreement with a study done in Nigeria that found that waste scavenging poses a great threat to the public. In addition, such dumpsites allow the growth of many pathogenic bacteria including those that may be MDR [11]. Human and animal scavengers were invariably at the site at all times.

This study's results show that the mean colony counts obtained from the dumpsite and garbage collection areas in residential areas and market places close to the dumpsite were relatively high. Among the dumpsites and garbage collection areas that had high CFUs, 70% were found in residential areas and 20% in market areas. In the dumpsites and garbage collection areas that had low CFUs, 57% were in residential areas and 14% in market areas. These high CFUs were probably as a result of the presence of fecal contamination and human activity in the dumpsites and garbage collection areas. The results obtained in this study correlates with that of Odeyemi, 2012 that showed that the mean total bacterial counts obtained from the dumpsite and in the residential area are relatively higher than those obtained at neighbouring streams or samples collected at least 50 m away from dumpsites [12]. This shows how fast resistant bacteria from the environment can gain entry into the human body through contamination from these dumpsites and garbage collection areas, thus creating high health concerns in the public health sector. It is also worthy of note that the heaviest bacteria burden in this study was found at Muthurwa estate dumpsite and that the least was at Dandora dumpsite. This may not be too surprising since Muthurwa estate dumpsite had fecal contamination and a high number of trespassers thus bringing and taking a high number of the bacteria with them. Dandora dumpsite was the only dumpsite with a structured management system. This is the largest dumpsite in East and Central Africa, where rubbish/garbage

from different parts of the city is dumped. This potentially offers a chance of transfer of pathogens from such sites to human residential sites since Dandora dumpsite is closely located to an ever busy residential area.

This present study also determined antibiotic resistance profile of *E. coli* and *Klebsiella* from the sampled sites. A high proportion of *E. coli* and *Klebsiella* strains were resistant to ampicillin (42%, 59%), streptomycin (46%, 46%) and trimethoprim/sulfamethoxazole (29%, 29%) respectively. While these values may be lower than those reported from clinical studies [13] These results suggest that resistance to antimicrobials is rising and this may be due to either the intrinsic resistance of many microorganisms to antibiotics or acquired resistance of the organisms enabled by the transfer of resistance of drug resistance plasmids. A high level of resistance has been found with members of the family *Enterobacteriaceae* which are increasingly becoming MDR. The origin of this resistance can probably be traced to the fecal constituent of the wastes or dump produced by people or animals that have been treated indiscriminately with various antibiotics and also to antibiotics production naturally by soil microorganisms [14]. The resistance prevalence of the two species was almost similar in all the antimicrobials used in this study. This indicates that the action of the antimicrobial to the two species works in an almost similar way thus the close resistance prevalence.

The highest multidrug resistance was found in Umama garbage collection area (71%), and the lowest multidrug resistance was found in Kenyatta staff quarter garbage collection area (4%). This difference may be due to the difference in diversity of dumpsites and garbage content and possible difference in the amount of human and animal fecal contaminants in different sites. Some sites recorded an MDR prevalence of more than 50% indicating that resistance to antimicrobials is on the rise and thus may lead to an increase in resistance related complications. The presence of high MDR phenotypes among environmental samples is an indication that resistant clinical samples are gaining entry into these sites. The possible factors driving the emergence of MDR phenotype could be the poor use of combined therapy.

5. Conclusion

Poor waste disposal and recycling practices are still rampant across the dumpsites and garbage collection areas. From the study, there was a high occurrence of *Klebsiella* and *E. coli* across the dumpsites and garbage collection areas indicating environmental contamination. Most of the dumpsites and garbage collection areas with high CFUs were found in residential areas indicating that contamination of the dumpsites and garbage collection areas maybe on the rise due to human interference. Isolates from dumpsites and garbage collection areas were resistant to a high proportion of the antimicrobials tested. This shows that clinical bacterial strains are gaining access into the environment thus the high resistance prevalence. The most effective antimicrobial was gentamicin to *E. coli* and

meropenem to both isolates. The most non-effective antimicrobials were ampicillin and streptomycin indicating that the future of the antimicrobials is at risk with the changing bacterial pressure. A high frequency of MDR isolates was recorded in the garbage collection areas than in dumpsites. These findings concluded that human activities during collection of the garbage could play a role in the contamination of the dumpsites with potential clinical isolates which can help spread antimicrobial resistance to the environmental strains.

Acknowledgements

Grateful acknowledgement is expressed to my able supervisors Ms. Winnie Mutai and Dr. John Kiiru for their continuous efforts towards making this study a reality. Few, if any, projects are written without the support and professional contributions of many people. This work is no exception. I admired my supervisors' patience, enthusiasm, motivation and immense knowledge they imparted to me during this period. They have guided me in the time of research and writing of this thesis.

Ethical Approval

Approved.

Authors Contribution

GW wrote the proposal and drafted the manuscript. She also did the lab work throughout the study. Ms. WM assisted in the cleanup of the proposal, drafting, and submission of the manuscript. Dr. Kiiru also assisted in the cleanup of the proposal and supervision of the laboratory work. Mr. MM and LO assisted in the laboratory and statistical analysis. All the authors read and approved the manuscript.

Authors Information

GW is a master's student at the University of Nairobi Medical Microbiology department. Miss. WM is a lecturer at the University of Nairobi Medical microbiology department who has vast experience in proposal presentation, writing, and microbial techniques. Dr. JK guided through the study and he is a senior researcher at the Kenya Medical Research Institute. MM and LO are graduate assistants working with the University of Nairobi who have a wealth of experience in laboratory research and data analysis.

References

[1] Ignatius, M. (2007) Isolation, Antibiotic and Heavy Metal Susceptibility Patterns of Some Pathogens from Domestic Dumpsites and Waste Water. Master's Thesis, Ahmadu Bello University, Zaria.

[2] Baquero, F., Negri, M.C., Morosini, M.I. and Blázquez, J. (1998) Antibiotic-Selective Environments. *Clinical Infectious Diseases*, **27**, 5-11. https://doi.org/10.1086/514916

[3] Goñi-urriza, M., Capdepuy, M., Arpin, C., Raymond, N., Caumette, P. and Quentin, C. (2000) Impact of an Urban Effluent on Antibiotic Resistance of Riverine *Enterobacteriaceae* Impact of an Urban Effluent on Antibiotic Resistance of Riverine *Enterobacteriaceae* and *Aeromonas* spp . *Applied and Environmental Microbiology*, **66**, 125-132. https://doi.org/10.1128/AEM.66.1.125-132.2000

[4] Wachukwu, C.K., Mbata, C.A. and Nyenke, C.U. (2010) The Health Profile and Impact Assessment of Waste Scavengers (Rag Pickers) in Port Harcourt, Nigeria. *Journal of Applied Sciences*, **10**, 1968-1972. https://doi.org/10.3923/jas.2010.1968.1972

[5] Mwaikono, K.S., Maina, S., Sebastian, A., Schilling, M., Kapur, V. and Gwakisa, P. (2016) High-Throughput Sequencing of 16S rRNA Gene Reveals Substantial Bacterial Diversity on the Municipal Dumpsite. BMC Microbial. *BMC Microbiology*, **16**, 1-12. https://doi.org/10.1186/s12866-016-0758-8

[6] Ahmed, A. (2011) Insect Vectors of Pathogens in Selected Undisposed Refuse Dumps in Kaduna Town. *The Scientific World Journal*, **6**, 21-26.

[7] Gonzalo, X. and Drobniewski, F. (2013) Is There a Place for Beta-Lactams in the Treatment of Multidrug-Resistant/Extensively Drug-Resistant Tuberculosis? Synergy between Meropenem and Amoxicillin/Clavulanate. *Journal of Antimicrobial Chemotherapy*, **68**, 366-369. https://doi.org/10.1093/jac/dks395

[8] Hellweger, F.L., Ruan, X. and Sanchez, S. (2011) A Simple Model of Tetracycline Antibiotic Resistance in the Aquatic Environment (with Application to the Poudre River). *International Journal of Environmental Research and Public Health*, **8**, 480-497. https://doi.org/10.3390/ijerph8020480

[9] Cheesbrough, M. (2006) District Laboratory Practice in Tropical Countries. Part 2. Tropical Health Technology, Cambridge. https://doi.org/10.1017/CBO9780511543470

[10] CLSI (2016) CLSI 2016 Antimicrobial Susceptibility Testing Guideline. CLSI, Location, **950**.

[11] Odeyemi, A. (2012) Antibiogram Status of Bacterial Isolates from Air around Dumpsite of Ekiti State Destitute Centre at Ilokun, Ado-Ekiti, Nigeria. *Journal of Microbiology Research*, **2**, 12-18. https://doi.org/10.5923/j.microbiology.20120202.03

[12] Odeyemi, A. (2012) Antibiogram Status of Bacterial Isolates from Air around Dumpsite of Ekiti State Destitute Centre at Ilokun, Ado-Ekiti, Nigeria. *Journal of Microbiology Research*, **2**, 12-18. http://article.sapub.org/10.5923.j.microbiology.20120202.03.html https://doi.org/10.5923/j.microbiology.20120202.03

[13] Njoroge, S. (2015) Phenotypic and Genotypic Resistance Patterns among Fecal *E. coli* Isolated from Severely Malnourished and Non-Malnourished Children Attending Mbagathi District Hospital, Nairobi. Master's Thesis, Kenyatta University, Kahawa.

[14] Ajayi, A. and Akonai, K.A. (2003) Antibiotic Sensitivity Profile of Microorganisms Encountered. *African Journal of Biomedical Research*, **6**, 79-84.