

A residential class-based comparative analysis of the intensity of illegal waste dumping in Gauteng, South Africa

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Abstract: Illegal dumping is a matter of concern particularly to local municipalities which are incapable of handling and managing volumes of waste produced from households. This study used a quantitative research design for fieldwork observation and structured questionnaires across three residential classes to assess the intensity and determinants of illegal waste dumping. Based on residential class (low, medium, and high), we found that the low-income areas had more problems of waste management compared to the medium and high-income residential areas. The low-income residents were without access to municipal waste collection services and opted to dump waste illegally. The Chi-square test showed positive significant relationship between the intensity of illegal waste dumping and several socio-economic variables of the respondents such as household income (12.063), gender (8.031), education (7.471) and age (7.945). We therefore suggest that besides communities taking initiatives such as recycling and composting if waste is not collected, urban stakeholders should be more focused on the highly low-income communities. The study has critical planning implications for sustainable waste management and environmental integrity.

1. Introduction

Solid waste management emerges as a threat to the United Nations global sustainability agenda; this is because of population explosion and unplanned urbanization (Aragaw et al., 2016; Ayaleru et al., 2018). However, the situation is critical in urban cities and communities of the developing world because of economic development, population growth, improving standards of living and technological advancement are accelerating the generation of waste resulting in complex and heterogeneous waste streams (Owamah et al., 2017). The lack of financial resources, weak institutional capacity, and policy framework among many, hinders effective management of solid waste by municipalities. This has exerted extensive pressure on local municipalities to provide effective and efficient municipal waste management services (Dlamini et al., 2019).

Many countries including the developed nations have pointed out diverse drivers associated with illegal waste dumping. However, distinct differences have been identified in literature between MSWM in developed and developing countries (Adipah and Kwame, 2019). Most developed countries' disposal technologies, recycling infrastructure and recovery rates provide sustainable management of MSW. Theoretically, the shortage of proper waste treatment facilities and disposal cost can increase the likelihood of illegal dumping (Liu et al., 2017). The empirical study by Liu et al (2017) revealed that in the United Kingdom, illegal dumping increased dramatically after 2012 due to the

introduction of charges for the collection of household items. While in Russia, the WasteTech, (2017) reported that the MSW recycling potential though estimated at 14 million tonnes, has an estimated 90% of waste disposed of indiscriminately due to lack of modern infrastructure, and efficient waste management scheme.

On other hand, the developing countries face the challenges of sustainable MSW management and the negative impacts of poor solid waste management on the environment. Several studies within the sub-Saharan Africa have attributed the illegal disposal of municipal solid waste to the inadequate budgetary allocation for effective waste operations; a lack of adequate waste minimization facilities, inadequate collection systems, unlicensed landfill sites which are poorly maintained and do not meet the standard of operations, inadequate waste collection infrastructure, among others (David, et al., 2020; Adipah and Kwame, 2019; Rasmien and Madyira 2019; Sotamenou, et al. 2019). At the micro-scale, household waste disposal choices are driven by the households' characteristics such as education, age, family size and available income (e.g., Binyaruka, 2015; Sotamenou, et al. 2019; Alhassan, et al., 2020).

The Constitution of the Republic of South Africa Act 107 of 1996 gives citizens of the country the "right to an environment that is not harmful to their health and well-being so that the environment is protected for the benefit of the present and future generations" (RSA, 1996). Waste Management Policy in South Africa is informed by the Schedule 5, Part B of the Constitution of the Republic of South African Act 108 of 1996 that mandate local government to perform cleansing function (RSA, 1996) while the National Environmental Management: Waste, Act 107 of 1998 (RSA, 2009) illustrates that municipalities are expected to deliver waste management services which include amongst other things, waste removal and disposal. The National Environmental Management Waste Act 107 of 1998 promotes waste minimization, reuse, recycling, and waste disposal that is considered as a last resort. The Municipal Act 117 of 1998, indicates that solid waste management is the competency of local government (RSA, 1998).

However, the Department of Environmental Affairs through the National Waste Management Strategy (RSA, 2011), acknowledges the challenges faced by South Africa with illegal dumping and solid waste management. Illegal dumping is the unauthorized disposal of waste or substances or materials to the land either onto private and/or public open spaces where no license or approval is granted. The situation has been compounded by the increase in the volumes of waste generated whereby an average person generates about 1 tonne of waste per year and three kilograms per day (RSA, 2017a). The province had 9.0 million tonnes of waste in 2012 and that increased to 15.86 million tonnes of waste by 2014 (RSA, 2017b). It is argued that the Gauteng Province generates approximately 35% of the total waste in South Africa because the province is the economic hub of South Africa with high population growth caused by pull factors and migration. Lack of human and financial resources, education, monitoring, and enforcement possess major threats to waste management. The situation results into increasing amounts of uncollected solid wastes and often most households' resort to unauthorised waste dumping such as informal and unregulated incineration, burying the waste, use of illegal dumping sites (streets and open fields), dumping in public places among others (Simatele and Etambakonga, 2015). The effects of illegal waste dumping include degraded public land, a decrease in property values, land contamination, land degradation, reduction of biodiversity value, contamination of running water, diseases, nuisance, increased risks and hazards, the unnecessary cost for local government for cleaning up (Meallem et al., 2010). Thus, illegal dumping is not only a nuisance to the environment but also creates vulnerability among the communities near the illegal dumping sites.

While previous studies in South Africa have examined the subject of waste management vis-a-vis illegal dumping related to enforcement-prosecution, income differentiation, extent of waste management facilities and access to landfills (Ochuko, 2014), only few studies have evaluated the socio-economic dimensions of challenges of

the waste management across residential classes in Gauteng urban environments. The previous studies have focused on the general illegal dumping and waste management problems prevalent in cities, without accounting for the variations across the residential classes (Ayaleru et al., 2018; Mannie and Bowers, 2014; Nkosi et al., 2013). Therefore, the residential-class based assessment provides new insights on the severity and intensity of illegal dumping taking into account the socio-economic elements of the areas. This study is important as it can provide basis for monitoring and cleaning up of such sites to avert the negative impacts of illegally dumped waste. Besides, the intensity of illegal dumping provides opportunities for residents to practice reuse and recycling of waste as alternative forms of waste treatment. The study's specific objectives are (i) to compare illegal waste dumping intensity across residential classes and (ii) to describe the determinants of illegal dumping across residential classes. The study's hypothesis is that "the demographic and socio-economic characteristics of the population (x) determines the intensity of illegal waste dumping."

1.1 Review of literature on causes of illegal dumping

The increase in the world's population has contributed to the influx of people moving from rural areas to affluent urban areas seeking better living conditions and employment (Daniel et al., 2013). The communities in rural areas often generate less waste due to socio-economic conditions emanating from less packaged products, few shopping areas, fewer manufacturing industries, and dispersed settlements (Bundhoo, 2018). On the contrary, as city residents' consumption patterns change and household income increases because of the capacity to afford packaged products, more tonnes of waste is generated; exceeding the carrying capacity of authorities responsible for waste management (Cole et al., 2014; Pakpour et al., 2014). Since the core function of local waste management directorates is to ensure that services are rendered for waste collected, the non-collection of household waste by municipalities drives residents to illegal dumping as an option for disposing of waste.

Literature on illegal waste dumping take cognizance with variations in waste generation based on residential urban classes characterized by varying income, living standards and frequency of waste collection (Daniel et al., 2013; Dladla et al., 2016; Widyaningsih et al., 2015; Bundhoo, 2018). A lack of adequate waste management service in low-income areas can exacerbate the increase of illegal waste dumping as compared to high-income areas where the collection of waste is done efficiently (Razack et al., 2017). The situation is often exacerbated by an increase in population, especially in the major cities. An increase in population in the city puts strenuous pressure on proper waste management in terms of proper separation, handling of waste and capacity to service all areas (Moh and Manaf, 2014; Muchangos et al., 2014; Ochuko, 2014; Ojeda-Benitez et al., 2003).

In addition, improvement in standards of living and economic growth results in the increase in the quantity and complexity of waste generated (Nkosi et al., 2013). This variation is influenced by varied consumption patterns which are determined by varied income levels. As it could be expected, higher income groups generate more waste compared to low- and middle-income groups. This is ascribed to affordability of products and purchasing power (Agola et al., 2011). However, in most cities, low-income groups are associated with high density population which translates to large amount of uncollected waste.

Among other socio-economic factors that influence illegal waste dumping are education, age, and gender. It has been found that households that are more educated and environmentally aware, are more likely to recognize the impact of poorly managed waste, and waste management plans (Khan et al., 2016). In other words, waste management challenges are further exacerbated by limited awareness, negative attitudes, personal beliefs, the level of education and individual conviction on waste

management responsibilities. These factors ultimately induce illegal dumping and increase of environmental pollution.

2. Materials and Methods

2.1. Study area

Figure 1 shows the selected study areas comprising of Sebokeng (ward 31), Vanderbijlpark (ward 9) in Emfuleni Local Municipality and Orange Farm (ward 5) in the City of Johannesburg Municipality. The areas selected were classified as high-income residential area (Vanderbijlpark); medium-income residential area (Sebokeng), and low-income residential area (Orange Farm). Vanderbijlpark is located along Latitude $26^{\circ} 41' 57''$ and Longitude $27^{\circ} 50' 8''$; Sebokeng is situated at Latitude $26^{\circ} 57' 65''$ and Longitude $27^{\circ} 83' 98''$, and Orange Farm is situated at Latitude $26^{\circ} 47' 71''$ and Longitude $27^{\circ} 83' 61''$.

According to the population census of 2010, the population of Sebokeng was 218 515, while the population of Vanderbijlpark was 95 840 and Orange Farm was 76 767 (StatsSA, 2011). Sebokeng and Orange farm economies include businesses such as beauty shops, pubs, petrol garages, night clubs, spaza shops, hair salons and shebeens. In Vanderbijlpark, 60% of the people are employed in factories, government, private businesses, shops, and other sectors (StasSA, 2016).

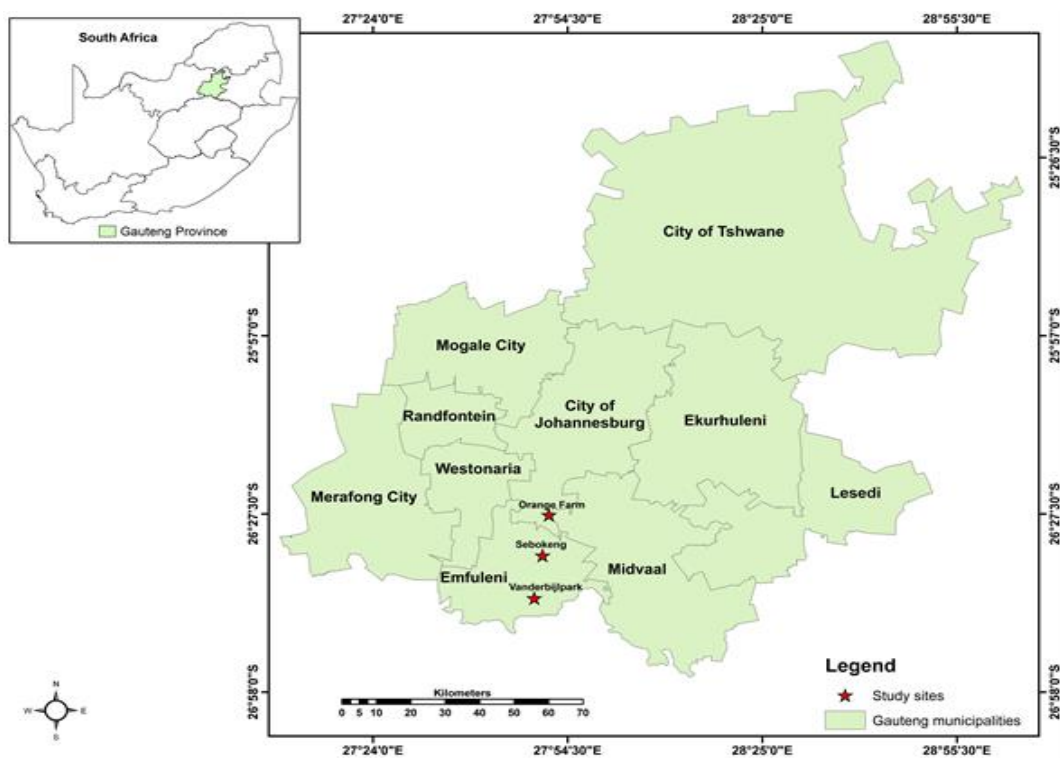


Figure 1. Map of the study area

2.2. Data collection methods and sampling procedure

This study employed a quantitative research design with two sets of primary data. The first set of primary data was drawn from a survey of 400 residents across the three study sites (Orange Farm, $n=180$; Sebokeng, $n=120$ and Vanderbijlpark, $n=100$) using structured survey questionnaire (see Appendix 1). The survey questionnaire comprised of three sections namely: (i) household demographic characteristics (ii) residential socio-economic characteristics and (iii) waste management services. The second set of primary data was the number of illegal dumping sites across the three residential classes sourced through direct field observation (counting) of the illegal waste dumps. A structured

observation schedule was used in a spreadsheet format for capturing observations (see Appendix 2). The primary data collected from questionnaires were supplemented with secondary data collected from Statistics South Africa census report of 2011, Community Surveys report of 2016 and municipal Integrated Development Plan (IDP) reports. These data consisted of socio-economic characteristics of the households across the three study areas.

The sampling frame consisted of all housing units in the three residential areas. Based on the Community Survey data of 2016, the population of housing units in Orange Farm was 21 029, Sebokeng was 60 793 and Vanderbijlpark was 30 892. A representative sample of 1140 (378 from Orange Farm; 382 from Sebokeng; and 380 from Vanderbijlpark) was obtained using a Raosoft sample size calculator (RaoSoft, 2020) providing a confidence level of 95% and a margin of error of 5%. However, a total of 400 responses were received.

The study adopted a stratified random sampling for the administration of the survey questionnaires. The sampling procedure involved three stages: (i) division of the sampling area into strata based on income; (ii) random selection of the designated number of housing units from each stratum; and (iii) randomly picking one household head (i.e., the survey participants) for interview making 400 respondents from the three study areas.

2.3 Data analysis

Data were coded using the Statistical Package for Social Sciences (SPSS 26.0 version) computing software. The analysed demographic characteristics comprises of gender, age, level of education and monthly income of the respondents and have been presented in tables as frequencies and percentages. To determine relationships between the intensity of illegal waste dumping and socio-economic variables (income, gender, education, and age), Chi-Square tests were computed. For this study, Chi-Square (χ^2) and p-values of the correlations were considered statistically significant at a 0.05 level of significance.

3. Results

3.1. Demographic characteristics of respondents

Table 1 shows information on four key socio-economic indicators of households covered in this study. The first attribute observed was gender distribution across the three study areas. As can be seen in Table 1, Orange Farm responses were 64.4% (male) and 35.6% (female), Sebokeng had 47.9% (male) and 52.1% (female) while Vanderbijlpark the responses were 43.1% (male) and 56.9% (female). Vanderbijlpark recorded the highest population of females (56.9%) when compared to Sebokeng (52.1%) and Orange Farm (35.6%). As can be seen in Table 1, in Orange Farm, 49.4% of the respondents were of the age group 18-35 while 50.6% were 36 years old and above. In Sebokeng, a similar pattern was observed whereby 45.5% of the respondents were between 18 and 35 years old, and 54.5% were above 36 years old. In Vanderbijlpark, responses showed that 35.3% were in the age group 18-35 and 64.7% were 36 years old and above. Orange Farm recorded the highest number of respondents (49.4%) in the age group, 18-35, which showed a younger generation compared to Vanderbijlpark which recorded the highest number of respondents in the age group of 36 and above (64.7%) and Sebokeng had 54.5%. Age (mostly older generation) contributes significantly to partaking in recycling of household solid waste (Moh and Manaf, 2014). The results observed in this study suggest that respondents in Vanderbijlpark and Sebokeng are more likely to contribute to waste management through recycling compared to the residents in Orange Farm.

Table 1. Demographic characteristics of respondents

Study site	Demographic variables	Frequency	Percent	
Orange Farm (n=180)	Gender	Male	64	64.4
		Female	116	35.6
	Age-group	18-35	89	49.4
		36 and above	91	50.6
	Level of education	Never went to school	16	8.9
		Grade R-7	54	30.0
		Grade 8-12	94	52.2
		Tertiary	16	8.9
	Income	R0-R7500	158	87.8
		R7500-R15000	22	12.2
Above R15000		0	0	
Sebokeng (n=120)	Gender	Male	58	47.9
		Female	62	52.1
	Age-group	18-35	55	45.5
		36 and above	65	54.5
	Level of education	Never went to school	0	0
		Grade R-7	4	3.3
		Grade 8-12	78	65.3
		Tertiary	38	31.4
	Income	R0-R7500	57	47.9
		R7500-R15000	59	48.8
Above R15000		4	3.3	
Vanderbijlpark (n=100)	Gender	Male	43	43.1
		Female	56	56.9
	Age-group	18-35	36	35.3
		36 and above	64	64.7
	Level of education	Never went to school	0	0
		Grade R-7	0	0
		Grade 8-12	36	35.3
		Tertiary	64	64.7
	Income	R0-R7500	4	3.9
		R7500-R15000	20	19.6
Above R15000		76	76.5	

Table 1 also shows information about education attainment across the three study areas. In Orange Farm, 8.9% of the respondents have never gone to school while 30% have completed between Grade R -7. Most of the respondents (52.2%) in Orange farm have completed Grade 8 to 12 and only 8.9% have some tertiary education. In Sebokeng, most of the respondents (65.3%) mentioned that they have completed Grade 8 to 12 while 31.4% have tertiary education. In the same study area, only 3.3% of the respondents indicated to have completed between Grade R-7. In Vanderbijlpark, the majority of the respondents (64.7%) have completed tertiary education while 35.5% mentioned that they have completed between Grade 8 and 12. Comparatively, the results show that Vanderbijlpark recorded the highest respondents (64.7%) with tertiary education than Sebokeng (31.4%) and Orange Farm having the least respondents in this category (8.9%). These findings suggest that Vanderbijlpark has the highest number of

people with the likelihood of having formal employment to potentially address illegal dumping through financial perspectives. Orange Farm recorded the highest response in the category of Grade R-7 (33%) compared to Sebokeng (3.3%) and Vanderbijlpark (0%) which shows that the highest number of people with no secondary education are in Orange Farm. Education plays a critical role in waste management, environmental sustainability and transitioning toward zero-waste tolerance (Muchangos et al., 2014). Furthermore, education contributes significantly to the upbringing of children to also understand waste as a resource and change behavior (Muchangos et al., 2014). As such, the findings in this study suggest that there could be negative waste management initiatives in Orange Farm due to lower education levels. However, although low level of education limits people to formal employment opportunities and environmental awareness, it could encourage the residents of Orange Farm to partake in recycling activities as a means of livelihood (Widyaningsih et al., 2015).

As can be seen in Table 1, many respondents in Orange Farm (87.8%) fall in the monthly income bracket of R0 to R7500, while only 12.2% earn between R7500-R15000. In Sebokeng, there were 47.9% in the category of R0-R7500, 48.8% in the income category of R7500-R15000 and 3.3% earn above R15000. In Vanderbijlpark, the majority of the respondents (76.5%) have a monthly income of above R15000, followed by 19.6% in the R7500-R15000 category while the least (3.9%) have monthly income of R0-R7500. Orange Farm has the highest percentage in the monthly income category of R0-R7500 (87.8%) compared to Sebokeng (47.9%) and Vanderbijlpark (3.9%). These results suggest that the residents of Orange Farm are more vulnerable in case of municipal failure to collect waste because they cannot afford to transport waste to the nearest transfer station or landfill thus more likely to illegally dump waste. Vanderbijlpark has the highest percentage of individuals with monthly income of above R15000 (76.5%) compared to Orange Farm (0%) and Sebokeng (3.3%) which illustrate that residents in Vanderbijlpark can afford to address illegal dumping in terms of financing transport to dispose of their waste in case of municipal non-collection. This research identified direct correlation between income levels and illegal waste dumping practices. In other words, income influences waste dumping whereby low-income groups contribute more towards illegal waste dumping due to the non-affordability of disposable income to transport and dispose of waste in licensed facilities (Al-Khatib, 2009; Al-Khatib et al., 2009).

3.2. Intensity of waste management services

3.2.1. Waste collection services

Table 2 provides information about frequency of waste collection by the municipality across the three study areas. Information presented shows that 50 % of the respondents in Orange Farm do not know the frequency of waste collection by the municipality, while 45.6 % mentioned that they do not receive municipality's waste collection services. Only 4.4 % know that waste is collected once a week. This represents a major concern for the community in Orange Farm to exacerbate illegal dumping with 45.6 % not serviced by the municipality.

In addition, information in Table 2 elucidates that in Sebokeng, 15.7 % do not know the frequency of waste collection, 84.3 % know that waste is collected once a week. However, although the majority know that waste is collected once a week, the respondents in Sebokeng indicated that no one receives waste collection services as per prescribed schedule which is a concern because, if waste is not collected as scheduled, people will dump it illegally. In contrast, 100 % of the respondents in Vanderbijlpark indicated that waste is collected once a week. The results reveal that in Vanderbijlpark, the municipality adheres to the South African minimum standards of waste collection which specifies minimum waste collection frequencies of not less than once a week (RSA, 2011).

Table 2. Frequency of waste collection by the municipality across the three study areas

Study site	Response	Frequency	Per cent
Orange Farm (n=180)	I don't know	90	50.0
	No collection	82	45.6
	Once a week	8	4.4
Sebokeng (n=120)	I don't know	19	15.7
	Once a week	101	84.3
Vanderbijlpark (n=100)	Once a week	100	100.0

3.2.2 Alternative waste disposal methods

The results in Table 3 indicate that 36.1 % of respondents in Orange Farm burn waste if it is not collected, while 63.9 % of the respondents indicated that they dump waste at night by the roadside. It should be noted that none of the respondents indicated composting and recycling as alternative waste disposal methods. In Sebokeng, 16.5 % of the respondents burn waste if it is not collected, 73.6 % dump at night by the roadside, whereas 9.9 % of the respondents either reuse or recycle their waste. There is no composting taking place in Sebokeng. In Vanderbijlpark, burning of waste and dumping waste at night by the roadside are not taking place. If waste is not collected, 60.8 % of the respondents are involved in using waste as compost whilst 39.2 % reuse/recycle the uncollected waste.

Table 3. Alternative waste disposal methods in Orange Farm, Sebokeng and Vanderbijlpark

Study site	Variable	Frequency	Per cent
Orange Farm (n=180)	Burn it	65	36.1
	Dump at night by the roadside	115	63.9
Sebokeng (n=120)	Burn it	19	16.5
	Dump at night by the roadside	89	73.6
	Reuse/recycle	12	9.9
Vanderbijlpark (n=100)	Compost	60	60.8
	Reuse/recycle	40	39.2

The study revealed that Orange Farm recorded the highest rate of burning waste at 36.1 % compared to Sebokeng (16.5 %) and Vanderbijlpark (0 %). The high proportion of burning waste in Orange Farm and Sebokeng contributes to air pollution. Burning waste by the community is done because of the non-collection of municipal solid waste by authorities contributing significantly to an increase in the levels of air pollutants (Bleck and Wettberg, 2012; Singh and Livina, 2015). Sebokeng recorded the highest number of respondents (73.6 %) who dump waste at night by the roadside compared to Orange farm (63.9%) and Vanderbijlpark (0 %). Like the results by Brown and Johnstone (2014), most companies and communities preferred dumping waste in open spaces and by the roadside at night to avoid law enforcement; thus, making the area vulnerable to the negative effects of illegal waste dumping. In addition, information presented in Table 4 reveals that in Orange Farm, recycling or reuse is not taking place which indicates a major concern compared to Sebokeng (9.9 %) and Vanderbijlpark (39.2 %) where some reusing and recycling of waste takes place. In Orange Farm and Sebokeng, there is no composting of waste compared to Vanderbijlpark (60.8 %) which illustrates that respondents in Vanderbijlpark assist in reducing illegally disposed waste by using waste as compost. Nonetheless, communities must be educated about other waste disposal

methods such as composting and recycling to minimize the illegal dumping of uncollected waste.

In addition, the study noted that the prevalence of illegal dumping sites was more in Orange farm where it was observed that there were 64 illegal waste dumps. Sebokeng had 46 observed waste dumps and the least (15) observed waste dumps are in Vanderbijlpark.

3.3 Determinants of illegal waste

Information on the relationships between intensity of illegal dumping and various demographic characteristics is established by using Chi-Square correlation analysis.

3.3.1 Intensity of illegal dumping and gender

Results for the Chi-Square correlation between gender and illegal dumping are presented in Table 4. The information in Table 4 indicates that there is a significant correlation between intensity of illegal dumping and females in Orange Farm χ^2 (df=1, n=116) =8.031, p=0.419, in Sebokeng χ^2 (df=1, n= 63) =5.686, p=0.140 and in Vanderbijlpark χ^2 (df=1, n=58) =4.011, p=0.316. The computed Chi-Square indicated a high relationship in Orange Farm (8.031), a moderate relationship in Sebokeng (5.686) and a low relationship in Vanderbijlpark (4.011) whereby the computed values exceeded the value in the table for p=0.05 and df=1 (Chi-Square 3.84). Previous studies outlined that females contribute positively towards keeping their areas clean to the extent of dumping any generated wastes away from their surroundings (Al-Khatib et al., 2009); hence females more likely to be involved in illegal dumping especially where waste collection services are minimal like in Orange Farm.

Table 4. Chi-Square correlation between intensity of illegal dumping and gender

Study site	Gender	Frequency	Correlation	Sig lev
Orange Farm	Female	116	8.031	.419
	Male	64	4.213	.325
Sebokeng	Female	63	5.686	.140
	Male	57	3.732	.023
Vanderbijlpark	Female	58	4.011	.316
	Male	42	3.642	.241

Furthermore, in Orange Farm, results show that there is a significant positive correlation between the extent of illegal dumping and the males (χ^2 = (df=1, n= 64) =4.213, p=0.325). These results could be attributed to the inadequate waste collection services prevalent in Orange Farm. Residents are left with no choice but to illegally dump the waste generated in their households. Similarly, it has been noted that inadequate waste collection by designated authorities results in illegally dumped waste in open spaces, most often adjacent to the community’s households (Moftah, 2016). However, in Sebokeng χ^2 (df=1, n= 57) =3.732, p=0.023 and Vanderbijlpark χ^2 (df=1, n= 42) =3.642, p=0.241, results revealed no relationship which could be attributed to the availability of waste collection services in these two study sites.

3.3.2. Intensity of illegal dumping and level of education

Information in Table 5 indicate that there is a significant correlation between intensity of illegal dumping and respondents in the grade R-7 category in Orange Farm χ^2 (df=1, n=54) =4.012, p=0.053. These results are similar to the research findings noted that lower levels of education contribute significantly to the intensity of illegal dumping (Muchangos et al., 2014). In essence, less educated individuals do not possess

environmental knowledge about the negative effects of dumping waste illegally; translating to increased intensity of illegal dumping.

The findings in Sebokeng indicated that there is no significant relationship between respondents with Grade R-7 education level and intensity of illegal dumping (χ^2 (df=1, n=4) =0.637, p=0.022). Thus, the prevalence of illegal dumping among the Grade R-7 respondents in Sebokeng could be explained by factors other than their level of education. Study results reveal that in Sebokeng, waste collection services by the municipality are done at least once a week but 15.7% of the residents do not know about the schedule (Table 2); hence, the respondents who do not know the schedule resort to illegal waste dumping.

Table 5. Chi-Square correlation between intensity of illegal dumping and level of education

Study site	Level of education	Frequency	Correlation	Sig lev
Orange farm	Never went to school	16	2.245	.053
	Grade R-7	54	4.012	.024
	Grade 8-12	94	7.471	.036
	Tertiary level	16	2.341	.011
Sebokeng	Grade R-7	4	0.637	.022
	Grade 8-12	79	5.612	.321
	Tertiary level	37	3.013	.052
Vanderbijlpark	Grade 8-12	34	3.054	.032
	Tertiary level	66	-5.231	.214

The Chi-Square results presented in Table 5 reveals that there is a relationship between the intensity of illegal dumping and respondents in the Grade 8-12 category in Orange Farm χ^2 (df=1, n=94) =7.471, p=0.036 and in Sebokeng χ^2 (df=1, n=79) =5.612, p=0.321. The tendency of illegal dumping in the two study sites could be attributed to inadequate waste collection services whereby residents resort to dumping waste illegally. Similar to the findings in this study, it has been noted that in Mangwanedi (Swaziland), secondary level respondents who hail from low-income areas contributed to illegal dumping (Abul, 2010). Coupled with limited waste collection services in Orange Farm and Sebokeng, respondents in the Grade 8-12 category opt to dump waste along the roadside at night. On the other hand, in Vanderbijlpark, respondents with Grade 8-12 education level are less likely to be involved in illegal dumping probably because in the high-income area of Vanderbijlpark, the municipality provides waste collection services at least once a week (Mannie and Bowers, 2014). In addition, study results revealed that residents in Vanderbijlpark are involved in composting (60.8%) and recycling (39.2%) activities (Table 3) as alternative forms of waste treatment.

In addition, Table 5 depicts a negative relationship existing between intensity of illegal dumping and respondents with tertiary education in Vanderbijlpark (χ^2 (df=1, n=66) =-5.231, p=0.214). This could be attributed to the majority of the respondents in Vanderbijlpark (66) having attained tertiary education and therefore it is assumed that they have environmental knowledge about the negative consequences of illegal waste dumping. Besides, Vanderbijlpark is a high-income area that is serviced by the municipality at least once a week and they are less likely to engage in illegal waste dumping. These results are supported by (Muchangos et al., 2014) which indicated that people who attended tertiary education do not partake in disposing of waste illegally due to affordability and they often practice proper waste management such as composting, recycling and dumping waste to the authorized waste facilities.

3.3.3 Intensity of illegal dumping and income

Table 6 is a summary of the Chi-Square correlation analysis depicting the relationship between the intensity of illegal dumping and monthly income.

Table 6. Chi-Square correlation between intensity of illegal dumping and monthly income

Study site	Monthly income	Frequency	Correlation	Sig lev
Orange Farm	R0-R7500	158	12.063	.000
	R7500-R15000	22	1.753	.022
Sebokeng	R0-R7500	58	7.317	.012
	R7500-R15000	59	8.032	.214
	R15000 and above	3	-0.421	0.27
Vanderbijlpark	R0-R7500	2	-0.345	.021
	R7500-R15000	20	1.651	.031
	R15000 and above	78	-9.441	.033

Information in Table 6 indicates a significant positive correlation between the intensity of illegal dumping and the respondents in the income category of R0-R7500 in Orange Farm χ^2 (df=1, n=158) =12.063, p=0.000 and in Sebokeng χ^2 (df=1, n=58) =7.317, p=0.012. Lower monthly income individuals are more likely to engage in illegal dumping since most of them cannot afford to transport uncollected waste to designated places (Al-Khatib et al., 2009). This is the case with residents in Orange Farm and Sebokeng who indicated that they do not have extra money to transport waste and also pay for private waste collection services. For Vanderbijlpark, results showed negative relationship χ^2 (df=1, n=2) = -0.345, p=0.021 between high-income respondents and illegal dumping which could be explained by the availability of waste collection services. As such, the intensity of illegal dumping is equally low in Vanderbijlpark as residents are serviced by the municipality, do composting and are also involved in recycling activities.

The result in Table 6 also indicates that there is a significant positive correlation between respondents who earn R7500 – R15000 and the intensity of illegal dumping in Sebokeng χ^2 (df=1, n=59) =8.032, p=0.214. The middle-income group contribute less to illegal dumping compared to the low-income group (Al-Khatib, 2009). However, for this study, in Sebokeng, illegal waste dumping might be attributed to other factors such as lack of knowledge about waste collection schedule (see Table 2), deliberate and probably the 'I don't care' attitude among some of the residents.

Information in Table 6 shows that there is a significant negative correlation between high income respondents (R15000 and above) and the intensity of illegal dumping in Sebokeng χ^2 (df=1, n=3) =-0.421, p=0.021 and Vanderbijlpark χ^2 (df=1, n=78) =-9.441, p=0.033. Abul (2010) indicated that high-income individuals can manage their households' waste properly through affordability to transport waste to waste facilities. The significant negative correlation in Vanderbijlpark indicates that income influences waste dumping; residents rarely dump waste illegally since it is collected by the municipality. In addition to affordability to transport their waste to designated dumping places, respondents reported that they sometimes compost and recycle uncollected waste. As the income of respondents increases, there is a simultaneous decrease in the amount of illegal dumping; high-income respondents can afford to transport waste to designated places in the case of uncollected waste.

3.3.4. Intensity of illegal dumping and age

Table 7 depicts information about the Chi-Square correlation analysis results depicting the relationship between the intensity of illegal dumping and age of the respondents. There is a significant positive correlation between intensity of illegal dumping and age in Orange Farm χ^2 (df=1, n= 89) =6.804, p=0.012 for the age group 18-35. Our results are similar to the findings by (34), which indicated that the age group

18-35 contributes significantly to illegal dumping. The situation is exacerbated by the lack of waste collection services in Orange Farm which forces individuals to dump waste illegally. The findings shown in Table 7 depicts that in Sebokeng χ^2 (df=1, n= 55) = 0.012, p=0.745 and Vanderbijlpark χ^2 (df=1, n= 34) =0.863, p=0.121, there is no significant correlation between age 18-35 and the intensity of illegal dumping. This could be attributed to the availability of waste collection services compared to Orange Farm; hence, despite being in the younger age category, the respondents are less likely to engage in illegal dumping.

Table 7. Chi-Square correlation between the intensity of illegal dumping and age

Study site	Age	Frequency	Correlation	Sig lev
Orange Farm Ward 5	18-35	89	6.804	.012
	36 and above	91	7.945	.009
Sebokeng Ward 31	18-35	55	0.102	.749
	36 and above	65	6.375	.323
Vanderbijlpark Ward 9	18-35	34	0.863	.121
	36 and above	66	0.612	.032

The results in Orange Farm χ^2 (df=1, n=91) =7.945, p=0.009 and in Sebokeng χ^2 (df=1, n=65) =6.375, p=0.323 shows that a relationship exists between intensity of illegal dumping and age group 36 and above. This could be attributed to other factors such as inadequate waste collection services, low to medium income levels and probably lack of environmental awareness. On the contrary, in Vanderbijlpark, χ^2 (df=1, n=66) =0.612, p=0.032 no relationship exists between age 36 and above and intensity of illegal dumping. Residents in Vanderbijlpark are less likely to engage in illegal dumping because most of the households fall within the high-income category and therefore can afford to transport their waste if not collected compared to middle and lower-income households. In addition, residents in Vanderbijlpark are involved in recycling and composting uncollected waste, hence, the less intensity of illegal dumping.

4. Discussion

The results of Chi-square test analysis indicate that illegal dumping of waste is influenced by drivers related to gender, education, age, and income. Similar to other studies, Sotamenou, et al. (2019) in Yaoundé Cameroun found that high-income respondents are less likely to opt for illegal disposal which could be explained by their higher education status and thus more aware of the environmental and health impacts of open dumpsites. Thus, improved education could help reduce the intensity of illegal waste dumping. However, in Hong Kong, Chu (2021) found that age and educational level were not influential factors affecting the respondents' intention to dump waste illegally. The author noted that due to the growing concerns about environmental protection, many opportunities are available to spread knowledge about environmental sustainability for all ages and all levels of education.

The intensity of illegal waste dumping is also influenced by the level of service provision by municipal authorities who have been overwhelmed by significant increase in MSW generation. Despite weekly formal waste collection being mandatory, it does not occur weekly with the low-income communities completely marginalized (Rasmeni et al., (2019). Exacerbating the situation is the general lack of MSW collection services hampered by inefficient waste collection services, lack of social pressure to prevent open waste dumping, and weak enforcement of local by-laws have led to an increase in the open dumping of household waste (Chikowore, 2021; Oyedotun et al., 2021).

The sociodemographic features across the three study areas have revealed disparities with the low-income areas forced to dump waste illegally if waste is not collected. Comparatively, the high-income areas are able to afford private waste

collectors if waste is not collected. These results are similar to the study by Nagpure, 2019 which revealed that the poor neighborhoods in Delhi, India solely depend on the Municipal Corporation of Delhi, and there is no private waste collector available. In other words, collection services are limited to mainly business areas and households that are willing to pay for the services (Fereja and Chemedda, 2022).

5. Conclusion and policy implications

This study focused on the comparative analysis of residential class-based illegal waste dumping and intensity of illegal waste dumping across three residential areas of Orange Farm, Sebokeng and Vanderbijlpark. This research disclosed the underlying driving socio-economic household variables that nominally contribute to household illegal waste dumping among the three study sites. It has been suggested and argued in this paper that illegal waste dumping is significantly influenced by gender ($\chi^2 = 8.031$, $p = 0.0419$); level of education ($\chi^2 = 7.471$, $p = 0.036$), age ($\chi^2 = 7.945$, $p = 0.009$), income variations ($\chi^2 = 12.063$, $p = 0.000$) and non-availability of municipal waste collection services. The primary issue identified due to inconsistent waste collection service is the prevalence of illegal dumps in Orange Farm while Vanderbijlpark and Sebokeng benefit tremendously from the frequent collection of waste in their areas

The socio-economic conditions prevalent in a particular area contribute positively or negatively towards illegal waste dumping whereby low-income households tend to dump waste illegally due to non-affordability and lack of municipal waste collection services compared to the high-income areas. Certainly, there are differences in the intensity of illegal waste dumping and municipality's service provision from one residential area to the other. Observations revealed that the majority of illegal dumps (64) were Orange farm compared to the 46 and 15 observed in Sebokeng in Vanderbijlpark respectively. This situation owes much to the lack of institutional capacity to provide waste collection services to all citizens as mandated by the South African Constitution. However, the negative effects of illegal dumping sites such as health risks due to the possible runoff of toxic chemicals, deterioration of the local landscapes, air pollution from burning waste among others; are not restricted to places where waste has been illegally dumped. The general urban population has the potential to suffer the consequences of illegal dumping and inadvertently crippling South Africa to attain good quality of life as envisaged by the United Nations' Sustainable Development Goals (SDGs). This study calls for the Municipality to deliver waste management services including waste collection to all residents within their jurisdiction.

The outcomes of this study have implications for urban management and sustainability. In view of this observation, it is of uttermost urgency to improve urban service provision in the Gauteng province where emphasis is placed on the importance of private, individual, community and citizens' group led initiatives for solid waste management to curb illegal waste dumping. Through effective and improved local community involvement and participation in activities such as composting, recycling and reusing, will facilitate commitment and responsibility by the community, both in terms of waste generation and management. For an effective waste management plan, local municipalities must foster partnerships with private and individual operators of recycling and buy-back centres. The establishment of buyback centres or transfer stations in low-income communities would promote waste reuse, recycling and address waste that is not collected. In other words, we urge that communities must be educated, empowered, sensitized about waste reuse, recycling and composting; and these activities must be incorporated into the formal waste management plans.

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Appendix: Appendix 1 shows the survey questionnaire and appendix 2 is the observation schedule.

Author contributions: LG Palamuleni: Data curation, Methodology, Formal analysis, Validation, Funding acquisition, Writing – review & editing, Writing – original draft, writing of original draft and editing. FE Tshabalala: Conceptualization, Data curation, Investigation, Methodology, Visualization, Funding acquisition, Writing – review & editing.

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Appendix 1: Questionnaire for general public regarding research titled: Residential class-based comparative analysis of household dumping in Gauteng, South Africa.

Please tick the box next to the most appropriate answer and tick by using the X on the box of your appropriate answer.

1. My Place of residence is?

Ward Orange farm

Ward Sebokeng

Ward Vanderbijlpark

2. Gender?

Male female

3. Age?

0-17

18-35

36 and above

4. Level of Education?

Never went to School

Grade R-7

Grade 8-12

Tertiary Level

5. What is the range of your monthly income?

R0-R7500

R7500-R15000

R15 000 and above

6. Do you have solid waste management problem?

Yes No

7. Where do you dispose your waste?

Bin	Open Space	Municipal collection
<input type="text"/>	<input type="text"/>	<input type="text"/>

8. Do you know illegal dumping?

Yes, I do No, I don't

9. How often is waste collected by the Municipality?

Once a week	Twice a week	No collection	I don't know
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

10. If waste is not collected, what do you do with the waste generated in your household?

Burn it	dump at night by the road side	reuse/recycle	compost
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

11. Why do you think that people dump: (do not read – can give multiple responses)

- A) Don't know where else to dispose of it.
- B) Too expensive to dispose of properly.
- C) Too much trouble to dispose of it properly.
- D) Can't get to disposal points (lack of transport).
- E) Don't care / can't be bothered / don't see it as a problem.
- F) Don't understand the consequences of dumping.
- G) They know they will more than likely get away with it.
- H) Trying to extend level platform area on own site.
- I) Other:

12. Besides municipal collection, what other means of disposing of rubbish are you aware of: can choose multiple options

- A) Take to recycling centre.
- B) Take to nearest transfer station or licensed landfill.
- C) Dump it on your site.
- D) Dump it elsewhere / vacant plot

E) Pay someone to take it away

13. How far would you be prepared to travel (one way) to dump waste at a licensed site?

< 2 km

2 – 5 km

5 – 10km

10 – 15km

15 km

14. Do you know that it is illegal to dump waste on any site that is not a licensed landfill, including your own site?

Yes No

15. What method do you use for storing domestic waste in your house?

Plastic bags

Single bin

Segregated based different bins

Specify any other methods

16. Do you know about rules on solid waste management & handling of solid waste?

Yes No

17. Whether different bins have been placed by municipal authorities for storage of municipal solid waste in your locality?

Yes No

18. Should Environmental education be taught at School?

Yes No No opinion

19. Is picking up waste around the community a fundamental responsibility of citizen?

Yes No No opinion

20. Do you know recycling?

Yes No I don't know

Appendix 2

ILLEGAL WASTE DUMPING OBSERVATION SPREADSHEET

Residential Districts	Sebokeng ward 31 observed waste dumps	Orange Farm ward 5 observed waste dumps	Vanderbijlpark ward 9 observed waste dumps
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