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The generation, use and disposal of waste crankcase oil in developing countries: A case for Kampala district, Uganda

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ABSTRACT

Waste crankcase oil (WCO), the oil that is removed from motor engines during an oil change, is frequently discarded into the environment, resulting in pollution of both aquatic and terrestrial ecosystems. In some developing countries, this common hazardous material is not properly managed. In Uganda little is known about its generation, utilization, and disposal. These factors were investigated using in-depth interviews of a sample of mechanics from 379 motor repair garages and 109 fuel stations in the Kampala district. Most garages (94%) and fuel stations (96%) in the study area offered oil-changing services. On average, each garage produced 62 l, and each fuel station produced 134 l of WCO per week. In garages 35% was sold, 16% poured on the ground, 18% taken by vehicle owners and 31% given away for free. At fuel stations, 49% was picked by private collectors, 27% sold, 4% poured on the ground, 2% burnt, 13% taken by vehicle owners, and 6% given away for free. Uses of WCO included coating roofing timber and fencing posts, use in timber cutting, marking play grounds, and pest control in animals. Its disposal involved burning, and pouring in the environment. Lack of policy and information for proper handling of WCO contributed to the poor management of WCO exhibited.

1. Introduction

Environmental exposure to chemical mixtures may adversely affect health [1–4]. Many such mixtures of a hazardous nature when released into the environment can impact human and/or wildlife via air, soil or water contamination. In many industrially developing countries, management of hazardous materials is not an awarded concern, with public health attention being particularly focused on immediate health problems such as infectious diseases, malnutrition, and infant mortality.

In this study, the generation, use and disposal practices of waste crankcase oil (WCO), which is a common hazardous waste, were investigated in the Kampala district, Uganda. Kampala is the capital city of Uganda and has an area of 195 km^2 and located 8 km north of Lake Victoria. The population in the city varies from about 1.2 million during the day to approximately 0.9 million at night. The human activity of this population far exceeds the infrastructure capacity of the city, leading to deterioration of the urban environment. The major sources of environmental degradation and pollution in the city include poor solid waste management, inadequate water drainage, industrial pollution, and pollution arising from the transport sector.

One of the sources of pollution from the transport sector is WCO. The WCO is removed from the crankcase (engine sump) when the engine is drained during an oil-changing procedure. Motor oil is used in motor vehicle engines to lubricate engine parts. Large amounts of motor oils are used worldwide, and a significant portion drips to road surfaces or is disposed off improperly. Due to the increasing production of lubricating oils and lack of proper treatment and disposal, WCO poses a serious threat to the environment [5,6].

Before they are used, crankcase oils consist of a base lubricating oil (a complex mixture of hydrocarbons, 80–90% by volume) and performance enhancing additives (10–20% by volume) [7]. Crankcase oils are altered during use because of the breakdown of the additives, contamination with the products of combustion, and the addition of metals from the wear and tear of the engine. During its use, polycyclic aromatic hydrocarbons (PAHs) as well as other polycyclic compounds are generated and accumulate in the oil [5,8–10]. However, the presence of PAHs has also been reported in unused motor oil [11]. There is also a build up of halogenated hydrocarbons in the oil, resulting from the chemical breakdown of the additive package, and also from the addition of chlorine and bromine that act as lead scavengers in leaded gasoline [12]. Lead build up in WCO could also be due to piston blow-by in engines

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using leaded gasoline. Uganda is still implementing the phasing out of lead from gasoline. The additives and their concentrations vary according to the type of oil whether it is for use in gasoline or diesel fueled engine. Additives break down in the engine and metals such as iron, copper, cadmium, zinc, manganese, chromium, barium, arsenic and lead appear in the oil, originating from parts of the engine due to wear [13,14].

Waste crankcase oil has been reported as a major source of petroleum hydrocarbon contamination in urban runoff [15–19], with large volumes entering aquatic ecosystems [17,19–21]. Although a continuous, low-level discharge of WCO into the environment may not be as dramatic as a single oil spill accident, the consequences could be more devastating over an extended period. Leaks from motor vehicles, and some other applications where WCO is applied, e.g. as a dust suppressant, also contribute to the loading of WCO in the environment [16,20,22].

Waste crankcase oil is a complex mixture comprising thousands of chemicals with largely unknown biological activity, however it is both mutagenic and carcinogenic [16,22,23]. Schreiner and Markerer [24] reported the mutagenic behaviour of WCO, which they mainly attributed to the presence of PAHs. PAHs are ubiquitous environmental contaminants with their distribution primarily being due to the incomplete combustion of fossil fuels, wood and other organic material, oil spills and the degradation of manufactured materials such as lubricating motor oils, detergents, and plastics [10,25].

The presence of PAHs in WCO is of profound public health significance given the fact that huge amounts of WCO are disposed off in the environment. In recent years, PAHs have also been characterized as having estrogenic response modulating potentials exhibiting estrogenic and/or anti-estrogenic activity [26–30], and possibly androgenic and anti-androgenic activity [31]. The anti-estrogenic potency has been reported to increase with concentration of 3–5 ring PAHs in a sample of two crude oils and a slurry oil [32].

In many industrially developing countries, oil-changing operations are performed at fuel stations and in garages, whereas in some industrially developed countries a significant number of individuals (Do-It-Yourselfers, DIYs) change their vehicle oil. A study done in Lebanon indicated that DIYs were non-existent and approximately 90% of oil changes occurred at fuel stations and in garages [33]. Sources of WCO in the environment range from individuals who change the oil in their motor vehicles and indiscriminately dump it, to the large establishments that discard the generated oil [8,15]. The lack of policy and economic incentives to recycle WCO, especially in industrially developing countries, increases the concentrations of petroleum hydrocarbons in the environment, which is of significant public health concern.

Approximately 80% of the vehicles imported into Uganda are used vehicles. It is estimated that approximately 350 motor vehicles are registered every week in the country and, of these, approximately 50% are retained in the Kampala district. The number of vehicles in the Kampala district has been estimated to be about 40,000. There are 156 fuel stations and over 3250 garages, both roadside and well established ones, in the Kampala district.

Oil-changing operations are mostly conducted at garages and at fuel stations. However, despite the generation of huge amounts of WCO at these places, no study has been conducted to document the generation, use and disposal of WCO in the country. Since it has been illustrated that WCO has the potential to impact health [4,24,34–36], this study investigated the volume of WCO generated and the uses and disposal in garages and fuel stations in the Kampala district to estimate the threat of this very common hazardous substance.

Table 1
Parishes in the five divisions of Kampala district where the survey was conducted

Central division Kisekka, Kagugube, Kisenyi I, Kisenyi II, Kisenyi III, Mengo, Old Kampala, Bukesa, Kololo I, Kololo II, Kololo III, Kololo IV, Nakasero I, Nakasero II, Nakasero III, Nakasero IV, Kamwokya I, Kamwokya II, Civic centre, Industrial area, Mengo, Nakivubo Shauriyako
Kawempe division Kyebando, Kanyanya, Komamboga, Mpererwe, Bwaise I, Bwaise II, Bwaise III, Kawempe I, Kawempe II, Makerere I, Makerere II, Makerere III, Wandegeya, Mulago, Kikaya, Mulago I, Mulago II, Mulago III, Kazo ward, Makerere University, Makerere Hospital
Makindye division Kasanga, Nsambya Central, Kabalagala, Kibuli, Wabigalo, Bukasa, Kisugu, Ggaba, Kibuye I, Kibuye II, Makindye I, Makindye II, Lukuli, Luwafu, Katwe I, Katwe II, Buziga, Salaama
Nakawa division Ntida, Kiwatule, Mutungo, Butabika, Mbuya I, Mbuya II, Banda, ITEK, Nabisunsa, UPK, Kyambogo Upper estate, Kyambogo, Kyanja, Bukoto I, Bukoto II, Bugolobi, Kiswa, Nakawa, Naguru I, Naguru II, Luzira
Rubaga division Najjanankubi I, Najjanankubi II, Nateete, Kasubi, Kabowa, Nakulabye, Rubaga Parish, Namirembe-Bakuli, Lungujja, Ndeeba, Busega, Lubya, Mutundwe

2. Materials and methods

2.1. Study design

A descriptive cross-sectional design using quantitative methods was used to answer the questions that guided the survey. Pre-tested structured questionnaires together with observational checklists were utilized by research assistants to obtain the data. The face-to-face interviews took place at the mechanics work place. This approach enabled the interviewees to feel more relaxed and to keep working during the interview session.

2.2. Study area and population

The survey was conducted in the parishes within the five administrative divisions of the Kampala district, namely, Kampala Central, Kawempe, Makindye, Nakawa, and Rubaga divisions as indicated in Table 1. The study population was comprised of mechanics at fuel stations and in roadside and fully established garages.

2.3. Sample size and sampling procedure

A sample size of 100 respondents was selected from each division, making a total sample size 500 respondents for the whole district. In each division, 80 mechanics from garages, and 20 from fuel stations were targeted as respondents.

A mechanic was defined as any individual engaged in motor vehicle repair and maintenance in a garage or at a fuel station.

2.4. Data analysis plan

Following data entry, descriptive statistics were used to examine the data for any unexpected outliers that may indicate data entry or coding errors. In addition, basic univariate statistics such as frequency distributions and means were calculated to characterize the study sample. Quantitative data analysis techniques that included

use of EPI Info, SPSS and SigmaPlot software were used to analyze and present data obtained.

3. Results and discussion

3.1. Socio-demographic characteristics

The number of garage respondents was 379 and distributed as follows in the five Kampala district divisions: Kampala Central 20.6% (78); Kawempe 23.8% (90); Makindye 19.0% (72); Nakawa 15.8% (60); and Rubaga 21.1% (80). At fuel stations we set a goal of 109 with 20 from each division with the distribution as follows: Kampala Central 18.3% (20); Kawempe 22% (24); Makindye 18.3% (20); Nakawa 22.9% (25); and Rubaga 18.3% (20). Of the 488 mechanics involved in the survey, only 1.6% were women, a female-to-male ratio of 1:60. Very few females engage in this occupation.

Fuel stations that were included in the survey included: Shell, Gapco, Total, Fina, Delta, Mogas, Spell, and Petro. An approximate number of fuel stations sampled were obtained by calculating from the number of fuel stations that were skipped during the interviewing of respondents. Out of the 156 fuel stations in the Kampala district, 109 stations were involved in the survey.

3.2. Generation of waste crankcase oil

Only 5.8% (22/379) of the garages surveyed in this study did not offer oil-change services. From the 357 garages offering oil-change services, it was established that approximately 4195 vehicles have their oil changed in garages per week in the Kampala district area. This is approximately 12 vehicles serviced at each garage every week. On average that suggests that each garage conducts two oil-change operations per day. However, the busiest garage conducts oil-changes on 38 vehicles per week, which are approximately five to six vehicles per day. There are approximately 3252 garages in the Kampala district; however, the exact number is difficult to establish since some are not registered.

The study established that on average approximately 60 l of WCO are generated by each garage per week. Of the fuel stations involved in the study, 96% (105/109) offered oil-change services. It was established that on average, 12–13 vehicles have an oil-change at a fuel station per week. The number of vehicles attended to at fuel stations decreased as the distance from the city centre increased. Generation of small volumes of WCO regularly is of higher health concern than the occasional generation of high amounts, which could be easily noticeable once introduced into the environment. The more frequent the oil-changes, the higher the volumes that accumulate and have to be disposed.

The frequency of having oil-changes was investigated. The practice of changing oil after fixed time periods and not after specific traveled distances was common for public commuter vehicles. It was reported that most diesel-fueled public commuter taxi vehicles had their oil changed every week, whereas for the petrol-fueled taxis it was every two weeks. It was established that speedometers in some of these vehicles get disabled by the drivers so that vehicle owners do not know the distance traveled by the vehicle, which distance would otherwise tally with the amount of money collected for the day. With disabled speedometers it would be impossible to determine traveled distance. In privately used vehicles, oil-changing is performed after a specific distance has been traveled depending on the brand of oil used. However, in some vehicles instead of having full oil-changes, the engines get partially drained and then filled with fresh oil. This practice, which was more common in privately owned vehicles, was reported to occur mainly due to financial constraints plus lack of information about the importance of a complete oil-change during vehicle servicing.

There were no standard containers used for collection and storage of the drained WCO at all the oil-changing facilities. The containers used included basins, tins, and plastic jerrycans and in some garages vehicle parts, e.g. engine sumps, were being used. One fuel station did not have storage facilities. Of the fuel stations that had storage facilities, 5.8% (6/104) were found to be insufficient. In garages, 10.4% (37/357) did not have storage facilities for the drained WCO, and of those that had, 50.6% (162/320) were found insufficient for the purpose.

3.3. Use of waste crankcase oil

There exists a broad range of buyers for the WCO from garages and fuel stations as shown in Fig. 1a and b. The mechanics were asked the uses to which the WCO was put, and the responses are shown in Fig. 2a and b. The four most common uses of WCO, showing responses from garages and fuel stations respectively were, use in treating building and roofing timber 27.5% and 31.4%, treating fencing posts 26.5% and 24.4%, use in timber cutting 18.6% and 12.8%, and marking of school play grounds 7.4% and 10.5%.

The WCO gets smeared on building poles, roofing beams and fencing poles to prevent wood rot and termite infestation. In the latter application, poles can also get soaked in boiling WCO. Lumbermen use the WCO during tree felling and also in sawing of the felled trees. The oil is used for marking lines on the timber and to

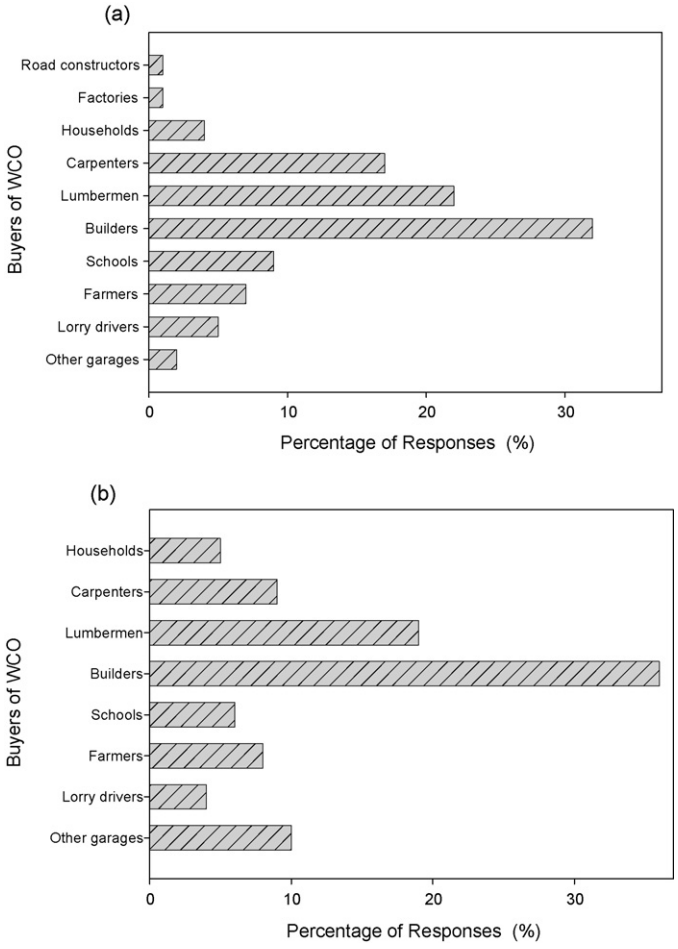

Fig. 1. (a) Buyers of waste crankcase oil from the garages. (b) Buyers of waste crankcase oil from the fuel stations.

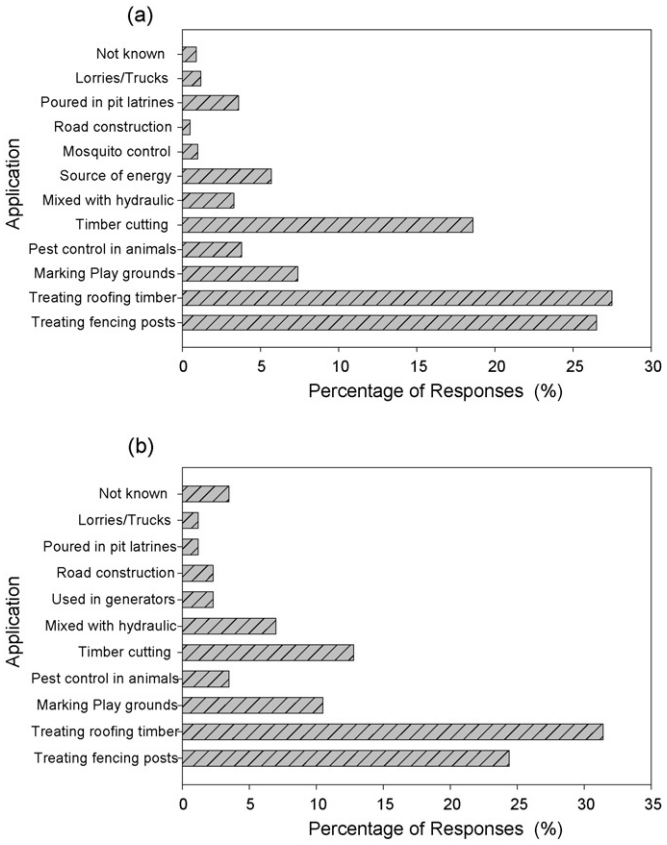

Fig. 2. (a) Applications to which waste crankcase oil is put after being obtained from fuel stations. (b) Applications to which waste crankcase oil is put after being obtained from garages.

cool and lubricate chain saws used for cutting. A substantial volume gets used in timber yards for sawing the timber into smaller sizes for sale.

A significant number of responses indicated that WCO was taken by schools for purposes of marking play grounds. The use of WCO is cheaper than the use of marking lime, which is costly and not readily available.

Responses on the use of WCO in farming operations were 3.8% in garages, and 3.5% at fuel stations. In farming, uses for WCO included spraying around animal houses to keep away red ants and on wooden stands to prevent termite infestation. Some farmers smear the WCO on maize cobs in the field to keep away monkeys, while others smear it on pig skin to control pests, such as mange, lice and ticks. The use of WCO to control mange in pigs has been documented in Kikuyu Division, Kenya [37]. The application of WCO on animals intended for human consumption is of potential public health significance. Since the WCO contains PAHs and other contaminants as already indicated, its use exposes the pigs to these contaminants and there exists a likelihood of humans being exposed through meat consumption.

There is also a potential of exposing the pigs to the potent anti-estrogenic contaminants contained in WCO [4], e.g. PAHs that have been reported to potentially modulate estrogen functions [28–30]. Some mechanics reported that farmers had observed that when sows were smeared with WCO, the proportion of male piglets in the litter significantly increased compared to those from sows that were not smeared with WCO. This information suggests a hypothesis that WCO does affect the reproductive capability of pigs and therefore controlled investigations are highly desirable. A few studies have examined the ability of environmental pollutants to act as both anti-estrogens and anti-androgens [38,39], leading to permanent alterations in gonad size [40].

Responses for WCO being poured into pit latrines to kill maggots and flies, and to supposedly reduce bad odour from the pits were 4% in garages and 2% at fuel stations. In many urban poor areas, the management of pit latrines is poor, which results in quick filling-up of the pits and becoming water logged. These result in the generation of offensive odour and emergence of maggots from the pit onto the floor of the latrine especially in rainy seasons. The water-logged pits also act as breeding places for mosquitoes, so a thin layer of WCO spread on the water within the pit reduces the mosquito population and, therefore, of malaria in the urban poor communities many of which are in such water logged places. Application of WCO delays the faecal degradation process in the pit. The use of WCO in pit latrines can be avoided by maintaining a high carbon/nitrogen ratio in the pit, which can be done by introducing dry carbon source materials, such as wood shavings, dry grass and leaves, wood ash and powdered charcoal into the pit. These materials have been reported to be effective in pit latrine management [41,42]. WCO is also applied on stagnant water in ponds to kill mosquito larvae, 2% in garages. Other responses included the use of WCO as a cheap dust suppressant during road construction, 1% (garages), and 2.5 (fuel stations), re-use in other vehicles, 2% at both garages and fuel stations and as an energy source for making fires, 6.5% in garages.

3.4. Disposal of waste crankcase oil

The methods through which the generated WCO was disposed off from garages and fuel stations were similar but varied in magnitude as seen in Fig. 3a and b. Of the responses as to what was done with the drained WCO in garages, 35% (204/581) indicated selling as the major option. Fifty-three percent of the garages sold all the oil they drained (108/204). At fuel stations 27% (30/110) responses indicated that the drained WCO was sold, and of these, 80% (24/30) sold all they generated.

In garages, 31% (179/581) of the responses indicated that WCO was given away for free, especially when the money offered for it was too low and also when they had no storage space for the oil. At most garages and fuel stations, the price per litre of WCO was approximately 13 US cents, which is equivalent to US$ 2.60 for a 20 l container. However, prices were not fixed, fluctuating depending on who the buyer was, how much they were buying, how desperate they were and also on how much was available at the time of sale.

Significant volumes of WCO got disposed off directly into the environment, with garages (16%) pouring more on the ground than fuel stations (4%). This was because many of the fuel stations had adequate storage facilities for the drained WCO. Most of the work areas in garages were bare soil that could be used for disposal, whereas at fuel stations all the work areas were paved with concrete. From the estimate that approximately 11.75 vehicles have their oil changed every week at each garage within Kampala city, in a year there would be 1,986,972 oil-change operations in approximately 3252 garages. From this research, it was established that at an oil change, only 27.2% of vehicles do have a full capacity of crankcase oil in their engines. Therefore working at a conservative estimate that each vehicle would be having 3.5 l remaining, a total of 6,954,402 l of WCO is generated in garages. Since 16% of the garages indicated that they dispose their WCO in the environment, the environmental burden of WCO from garages within the Kampala district area is 1,112,704 l (approximately 1.1×10^6 l). From fuel stations, the annual generation from 12.5 vehicles per week at each of 156 fuel stations with 3.5 l WCO yield per oil-change operation is 354,900 l (approximately 3.6×10^5 l). It was established that 4% of fuel stations disposed off their WCO directly into the environ-

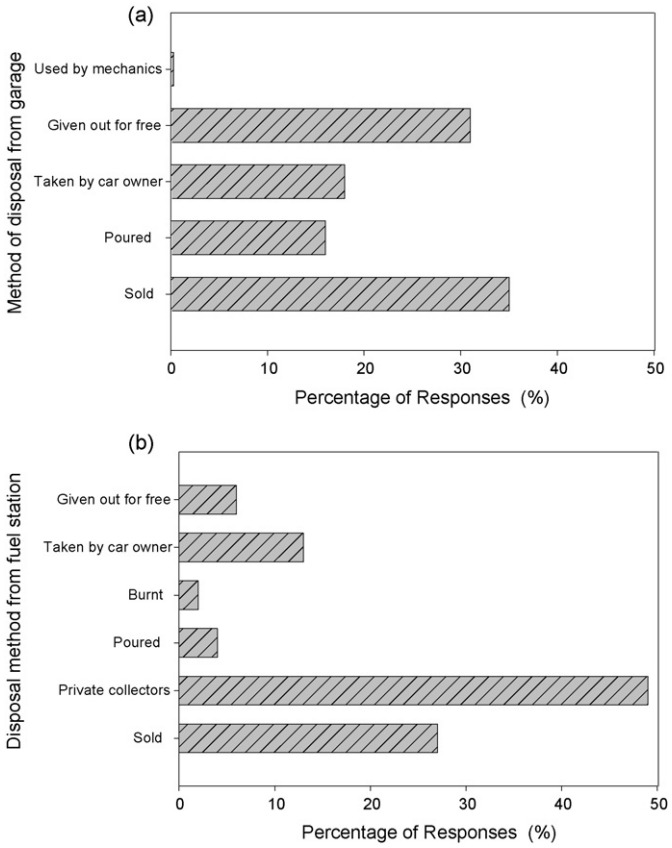

Fig. 3. (a) Disposal methods for waste crankcase oil from garages. (b) Disposal methods for waste crankcase oil from fuel stations.

ment, making the annual environmental burden from this source 14,196 l (approximately 1.4×10^4 l). The total annual environmental burden of WCO from both the garages and fuel stations in Kampala city is of 1,126,900 l (approximately 1.1×10^6 l), a figure of significant public health concern. The total environmental burden of WCO is much higher than this because WCO is put to many uses, some of which result in the release of the WCO back into the environment. For example its use in road construction and in marking play grounds, both of these applications result in releasing the WCO components into the environment. In the USA it was estimated that about 4.2×10^9 l of waste motor and industrial lubricants were lost to the environment annually [20]. In Nigeria, over 5×10^6 l of WCO are generated annually and disposed on land or drains thereby constituting a major land-based source of inland water, coastal and marine pollution [43].

Some of the WCO was poured in water ways that lay adjacent to the generating facilities. At fuel stations that poured the WCO into the environment, 50% admitted it was the accepted method of disposal. The estimated input of WCO into aquatic environments from garages is 22.7% of the total disposed WCO, which is equivalent to 2.5×10^5 l annually. In garages, where disposal into the environment was done, the options are as shown in Table 2. Those who knew that the method of disposal that was being used was wrong were 51%.

The frequency of pouring WCO in the environment varied between garages, with the majority 41% (38/92) pouring some of it on a daily basis. Those that poured it out as they deemed necessary depending on the availability of dust to be suppressed or stagnant water around the work places were 11% (10/92). In instances where less than 5 l of WCO were generated, it got poured away most times since the minimum volume for buying or selling was 5 l.

Table 2
Places where waste crankcase oil is deposited into the environment from garages

Location	Number of respondents	%
Pit or trench	15	12.6
Waterway	27	22.7
Ground surface	68	57.1
Garbage skip	4	3.4
Urinals	4	3.4
Stagnant water	1	0.8
Total	119	100

The study indicated that some WCO was taken by the vehicle owners; this was the case for 18% of garages, and 13% of fuel station responses. At fuel stations, the biggest fraction of the generated WCO (48%) was taken by licensed private collectors on behalf of the petroleum companies although the respondents did not know what the WCO got used for thereafter. However, it was established that most of this collected WCO got sold to small-scale foundries in Kampala, and neighbouring districts and to road constructors. Burning as a disposal option was acknowledged at two fuel stations, where it was used when there was lack of storage space for the WCO.

In all the garages and fuel stations, there was lack of specific policies to regulate WCO disposal. As a result, there was indiscriminate disposal of WCO in the environment. Many mechanics, 79% in garages 36% at fuel stations, had never received any training or information about hazardous substances in their work environment and were very receptive to the idea of having dissemination seminars to educate them on the hazardous substances, which they handle on a day-to-day basis in their work environment. This shows that there is a need for information about hazardous substances, especially for the mechanics in garages.

4. Conclusions

In the Kampala district, Uganda, oil-change operations are principally performed at two types of locations; roadside garages and at fuel stations. There are approximately 3252 garages and 156 fuel stations. From these locations, substantial volumes of WCO are generated. A total of approximately 22,000 l of WCO is generated from roadside garages every week. At fuel stations, approximately 14,000 l are generated per week.

There was no segregation of the different types of oils when they got drained from the vehicles. All drained oils were being collected in the same container. Absence of a large-scale WCO recycling programme in the country has resulted in significant amounts being disposed off in the environment.

A substantial volume of WCO (31%), according to responses, was given out for free, with almost a similar quantity being sold. Builders buy the bulk of the WCO, followed by lumbermen, carpenters, schools and farmers. Among the uses to which WCO was put are; treatment of roofing timber and fencing posts, used in timber cutting, and marking of school play grounds. Other uses included pest control in animals, as a source of energy, used for mosquito control, and as a dust suppressant during road construction.

There was no fixed price for purchasing WCO. The price varied depending on who the buyer was, on the quantity available and also the amount one was purchasing. The common price for a 20 l container of WCO was US$ 2.60.

Substantial volumes of WCO were reportedly taken by private collectors although the personnel at the fuel stations did not know its fate thereafter. The private collectors did not collect any WCO from the garages, and yet these produced the highest volume. At fuel stations where collection of WCO took place, the collection schedules in operation did not match with the storage capacities

in place. At most fuel stations (30%), collection was reported to be after every three months but there were no storage capacity to hold what was being generated for that long.

According to the responses, the amount of WCO that got poured into the environment from garages was four times that poured from fuel stations. Although burning was used as a disposal option at fuel stations, it was not used in garages.

Training and making available information on handling hazardous materials to the mechanics would significantly reduce on the poor handling and indiscriminate disposal of WCO into the environment as exhibited in the Kampala district. Establishment of re-refining and/or reprocessing as a strategy for WCO management in the country would significantly reduce the amounts of this common hazardous material being disposed into the environment.

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Glossary

Additives: substances that enhance and prolong the performance characteristics and life of the lubricating base oil; for motor vehicles, these additives include inorganic and aromatic organics

Crankcase: the housing for the crankshaft of an engine, where, in the case of a motor vehicle, oil from hot engine parts is collected and cooled before being pumped back to the engine

Crankcase oil: consists of virgin lubricating base oil and additives; it is used in the crankcase as a hydrodynamic lubricant to reduce friction, as a coolant, and to form a compression seal

Fuel station: a place which sells fuel (petrol (gasoline), diesel) for motor vehicles. Can also be called a filling station, fueling station, gas station or petrol station

Garage: Vehicle repair workshops where vehicles are taken for general repairs and servicing

Landlords: persons responsible for the place where the garage is located
Oil-change: operation of having crankcase/engine oil changed
Taxi: these are mini vans that have been converted to ferry passengers. The most popular ones in Kampala district have a carrying capacity of fourteen passengers
Waste crankcase oil: another name for used motor oil or used engine oil. It is the brown-to-black, oily liquid removed from the engine of a motor vehicle when the oil is changed. Waste crankcase oil is similar to unused oil except that it contains additional chemicals that build up in the oil when it is used as an engine lubricant