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HEALTH AND ENVIRONMENTAL FOOTPRINTS OF SPENT LUBRICATING OIL (SLO)

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Abstract

The increasing reliance on petroleum products since the 1990s has positioned lubricating oil as a vital component in industrial operations. However, the indiscriminate disposal of spent lubricating oil (SLO) after its useful life presents serious environmental and health hazards. Toxic substances in SLO disrupt the balance between biotic and abiotic components of ecosystems, leading to reduced species survival, reproductive issues, and potential extinction, ultimately threatening biodiversity and food chain integrity. This review adopts a comprehensive literature-based methodology, sourcing data from peer-reviewed journals, technical reports, and case studies accessed through databases such as Scopus, ScienceDirect, and Google Scholar. The analysis reveals significant adverse effects of SLO contamination, including organ toxicity, hormonal disruption, soil quality degradation, reproductive abnormalities, and biodiversity loss. These findings highlight the urgent need for improved disposal practices, stronger policy enforcement, and public education to reduce the long-term environmental and biological impacts of SLO pollution.

Keywords: Spent lubricating oil, Environmental pollution, Ecosystem degradation, Toxic contaminants, Sustainable waste management.

Introduction

Lubricating oil has for decades been known as a vital industrial driving force. It is a complex mixture of viscous hydrocarbons with high boiling point usually above 400^{0}C and this distinguishes it from other crude oil fractions (Speight and Exall, 2014). Its applications serve as corrosion inhibition, friction reduction, heat transfer medium, prevent wears and tears, reduce dust among others (Kannan *et al.*,2014). Though very important for the smooth and proper running of engines and other mechanical parts, its chemical components tend to break down over a period of application as a result of property deterioration experienced from wear and tears of engine parts (Mortier *et al.,* 2010). The waste oils generated are known as hazardous material and should be properly handled for environmental safety (Boughton & Horvath, 2004). Polycyclic aromatic hydrocarbons (PAHs), heavy metals, benzene, chlorinated solvents, carbon residue, ash, asphalt compounds are among the common pollutants found in SLO (Chung *et al.*, 2007, Riyanto *et al.,* 2018).

Lubricating oil is a mixture of base oil and additives and the main source of base oil is crude oil (Speight & Exall, 2014). Studies by Kheireddine and El-halwagi (2013) showed that the toxicity level of aromatic components of lubricating oil is increased by the use of additives and when disposed into the environment threatens life forms (Kanokkantapong *et al.,* 2009).

Akintunde *et al.,* 2015) reported that as the human population continues to grow coupled with industrial growth surge experienced around the world, intensive mechanization of agricultural practices and the high increasing transportation mediums, the volume of spent lubricating oil generated annually has been on the high rise.

Spent oil is therefore any oil either petroleum based or of synthetic origin which has become unsuitable for intended usage as a result of prolonged operations thus becoming contaminated by the presence of impurities either physical or chemical which has made the oil lose its initial desired properties (Ayadi & Ayedun, 2024., Ameh *et al.,* 2012). The loss of vital properties which are paramount to the efficient service life result in poor performance, increases both the chemical and mechanical wear rates and ultimately reduced life span of the machine (Gustavsson, 2013; Speight & Exall, 2014). Thus, replacement is the best option after which the lubricant has exhausted its needed properties for effective operations.

Several management practices have been explored in order to curtail the harmful impacts of these oils as majority of the quantity generated are usually disposed into the environment indiscriminately (Boadu *et al.*, 2019). Such practices range between the conventional and modern methods and are geared toward the recovery of the base oil which can then serve as feedstock rather than pure waste and source of environmental pollution. Among the processes employed in the recovery process are acid/clay method, solvent extraction, combined technologies, vacuum distillation, hydrotreating etc. Some of these methods yield good recovery rate; some however yield low results while some also produced acidic sludge which also find its way into the environment and as a consequence, have been banned in many countries as the quest for safer environment intensifies.

With high increase in technological advancements experienced around the world, particularly from the developed and some developing nations; and as human quest for high living standards soar, many nations now depend directly or directly on oil-based products. Among the fractional distillation products of petroleum, gasoline and heating oil stand more desired serving as fuel for various automobiles, energy source for heating homes and the various machines used in the industries. Other petroleum derived products include plastics, chemicals of varying applications i.e. cosmetics, agrochemicals, pharmaceuticals etc. altogether known as petrochemicals serve in no small measure in ensuring human living comfort.

Vegetable oils and animal fats though not petroleum based, their demands are also on the increase (Metzger & Meier, (2010). These oils can contain toxic components capable of producing physical effects comparable to those of petroleum based.

Because of their importance and high demand, they are often stored and transported in huge volumes. During exploration activities, storage or transportation of oil and oil-based products, spill can occur either on land or waterways and when this happens, it has a far-reaching effect on human health and that of the environmental quality aside the economic cost of clean-up and possible loss of some living organisms that cannot survive under such environmental condition.

Being so essential and central to the efficient operation of various machines and machine parts, cutting across various applications in diverse vehicular systems, aviation, marine, industrial and power generations. Conservation and best management practice for the continued use of this vital driving force should be given utmost priority giving the understanding that the chief source, crude oil is non-renewable with high market demand (Koçman *et al.*, 2025). Consequently, spent oil should be properly managed in order to save man, other life forms and the mother nature from its deleterious effects (Silva *et al.,* 2017)

Given the intricate nature, complexity and interdependence of life, this review sets to explore the various effects of spent lubricating oil on the environment, various life forms including man and offer possible suggestions for best management practices.

Methodology

This review adopts a comprehensive analysis of peer-reviewed journal articles, technical reports, and case studies obtained from reputable scientific databases such as Scopus, ScienceDirect, and Google Scholar. The selection process also focused on publications from the past 15 years (2010-2025) to ensure relevance and current perspectives with keywords such as *spent lubricating oil,* environmental pollution, toxic contaminants, sustainable waste management and ecosystem degradation that addressed recovery techniques, environmental impacts, and management practices of spent lubricating oils. This methodology ensured the incorporation of credible and relevant insights into current practices and research gaps in the field.

Results and Discussion

Effects on Human Health

Being at the receiving end of the food chain, man directly or indirectly depend on other living forms either plants or animals for his survival to which the environmental quality must support. Any form of instability to this balance ultimately affect man on the long run.

Human exposure to SLO can occur through direct or indirect contact and can have both acute and chronic health effects. Direct dermal contact can cause eyes and skin irritation, inhalation of fumes can cause dizziness. Indirect exposure is mostly through ingestion of contaminated food (cadmium in vegetables) or water. Studies have linked chronic exposure to SLOs with several health issues, including liver and kidney damage, neurological disorders, respiratory complications, and even carcinogenesis (Akinbinu *et al.*, 2023).

The effect of spent oil on human arises from human exposure to this material. Of all the known exposure routes like oral, inhalation, ingestion which are very common scenario particularly in places where the affected persons are exposed directly to water polluted with spent oil as their main drinking source or at workplace especially auto mechanic workshops where artisans are always in direct contact with the spent oil, dermal exposure is the most common (Christopher *et al.*, 2011). Other indirect exposure to SLO pollutants could arise from automobile and generator fumes, roadside particulate matters etc.

The harmful and severity effects produced by the pollutants varies from individual to individual depending on several factors including health background, age, nutritional balance, duration of contact, dose and route of exposure.

Depending on dose and contact time, health effects experienced from pollution of spent lubricating oil could be systemic, immunological, neurological, reproductive, genotoxic, carcinogenic effects and ultimately death in severe cases.

For acute toxicity, exposure is usually in days less than fourteen (14), while for intermediate toxicity, it is expressed in weeks to months (15- 365) and chronic toxicity is often expressed in years (365) days and above (ATSDR, 1997). The resultant health impact of spent oil on individual depends largely on the chemical composition of the oil, the dose acquired, route of exposure and duration of exposure. People residing around where metal, plastic or spent oil recycling plants are situated or areas where spent oils are used as fuels are at risk of high exposure via inhalation of PAHs, metal particles and various combustion products which contain hazardous compounds like polychlorinated biphenyls (PCBs), Chlorodibenzofurans (CDFs) and Chlorodibenzodioxins (CDDs) which are very deleterious to human health.

To fully understand the mechanism of action of the pollutants in spent lubricating oil, the fate of these chemicals within biological system is important. Depending on the chemical composition of the spent oil, the resultant health effects will be whether the pollutant is absorbed, stored or excreted from the body.

Granella & Clonfero,1991 while working on the fate of PAHs build up in spent mineral-based crankcase oil on mice, showed that the oil was absorbed on the skin of the mice. In similar studies, where cattle swallowed spent mineral-based crankcase oil showed that lead and some metals in the spent oil were absorbed and distributed to various organs including liver and kidney. This becomes worrisome and threatening as man depend directly on cattle for meat and milk production.

The understanding that the composition of the various lubricating oil varies based on application purposes also informs varied composition of the spent oil. As a consequence, effects experienced by exposure to one particular spent oil may be different to the other based on composition. However, mechanics and other automobile repairers who on daily basis are exposed to various oils (fresh and spent) as different automobile manufacturers specifies different oils for maximum performance are at greater risk of health impacts. Many of who were exposed to spent mineral-based crankcase oil experienced skin rashes, blood stool, headaches and tremors (nervous system perturbation) (Hazelett, 2005).

Aside direct exposure to spent lubricating oil, inhalation of mists from spent mineral base crankcase oil can cause eyes, throat and nose irritation. They are also exposed to various chemicals including those used for spraying and vehicle body works. It was reported that the intake of high volume of spent mineral-based crankcase oil can result to diarrhea (ASTDR, 1997). Even though the international agency for research on cancer (IARC, 1984) did not describe spent oil as a human carcinogen, Teresa *et al.,* (2005) in her investigation, identified PAHs in spent engine oil as cancer- causing agent in humans.

Effects on Endocrine and Reproductive System.

One of the toxicological effects associated with spent oil is endocrine disruption (ED) where certain compounds have been found to interfere with the endocrine system. Such compounds that are capable of causing endocrine disruption effects are known as endocrine disruptive compounds or chemicals (EDCs) (Warner *et al.*, 2020, Combarnous, 2017, Bergman *et al.*, 2013) and these include industrial chemicals (solvents and lubricants), pharmaceutics, plasticisers, personal and healthcare products, agrochemicals and flame retardants (Papalou *et al.*, 2019). Among the common EDCs are polychlorinated biphenyls (PCBs), bisphenol A (BPA), polybrominated biphenyl ethers (PBDEs), alkylphenols, furans, dioxins, halogenated hydrocarbons, phthalates, heavy metals and pesticides etc. They function by mimicking the naturally occurring hormones such as estrogens and androgens and exert their toxicity effects thereby altering the normal hormonal functions which promotes growth and development. As a definition, the American Endocrine Society defines EDCs as environmental contaminants capable of disrupting and disturbing the normal functioning of the hormonal system (Gore *et al.*, 2015). Because of the functional roles played by the endocrine system in maintaining very important physiological processes, EDCs can alter the normal hormonal functions thus changing the physiology and also disrupting the homeostasis of such organism (Gore *et al.*, 2015) via series of mechanisms thereby making such organism more susceptible to disease (Bornman *et al.*, 2017) and result to various health challenges (Karthikeyan *et al* ., 2019) including the likes of diabetes in humans (Han *et al.,* 2020), respiratory issues and abnormal reproductive development (Teng *et al.,* 2020, Jacobsen *et al.*, 2012). The effects of EDCs are not only limited to the exposed persons but also their progeny and future generations. During fetal and neonatal period, EDCs exposure can occur through placenta and breastfeeding and as such, pre and postnatal human development can be affected. It has been reported that as a result of maternal exposure, infants can be affected even before birth (Katsikantami *et al.*,2016). The effects of EDCs on male reproductive system are often attributed to the association of these chemicals with the function of steroid hormones that are responsible for the virilization of the Wolffian ducts (Sweeney *et al.*, 2015). The reproductive disorder in males that is associated with impaired fetal testis development varied in phenotype and time of manifestation. This disorder, often codename "testicular dysgenesis syndrome" (TDS) hypothesis (Skakkebaek *et al.*, 2016) range from hypospadias and cryptorchidism in infants (Thankamony *et al.,* 2014) to low testosterone levels, infertility, and testicular cancer (TC) in adult men (Eisenberg & Lipshultz , 2015). TDS has been linked to environmental factors during fetal life (Skakkebaek *et al.*, 2016). Studies conducted by (Hond *et al.,* 2002) on the effect of EDCs (PCBs & dioxin) on the pubertal period of eighty (80) boys revealed negative association between the PCBs exposure and pubertal stages with respect to genital maturation and the appearance of pubic hair. On the other hands, dioxin revealed no negative.

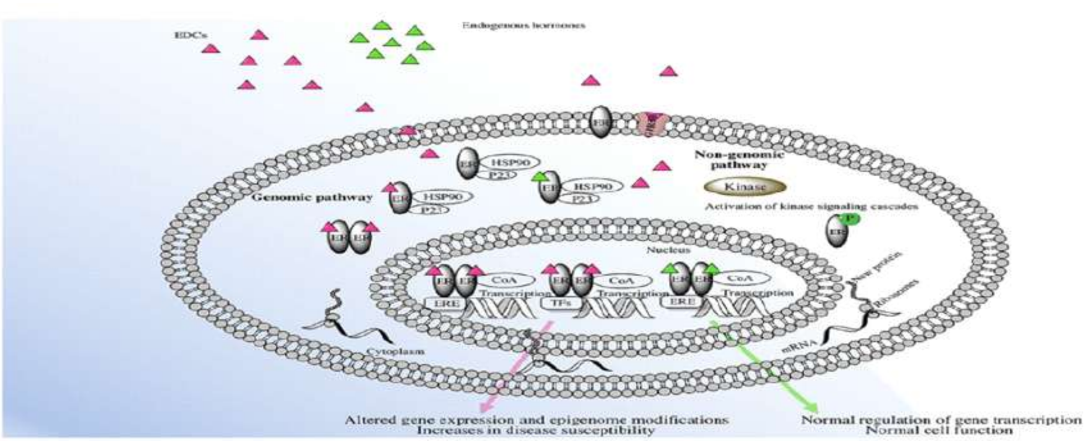

Fig. 1 Representation of endocrine disruption by EDCs: Adapted from Encarnação *et al.*, (2019).

Endocrine disrupting chemicals: Impact on human health, wildlife and the environment. Saiyed *et al.*, (2003) also reported a link between pubertal exposure to the pesticide endosulfan and low level of pubic hair, testis, and penis maturation were observed which suggest a delay in sexual maturation. Other study that was published in 2008 where 18 girls and 15 boys were exposed to dioxin-contaminated breast milk. The authors reported a delayed breast development in the females and a delayed age at first ejaculation was observed in the males (Leijs *et al.*, 2008). EDCs have also been found to have negative effects on anogenital distance (AGD). AGD is the distance between the anus and the external genitalia. The length in male is usually twice that of female newborns (Schwartz *et al.*, 2019). Often considered a wide biomarker capable of determining early androgen disruption and also predicting later life reproductive disorder in male progeny (Dean & Sharpe, 2013). The action of androgen before birth determines reproductive organ size and anogenital distance and this action has been found to be disrupted by EDCs (Diamanti-Kandarakis *et al.*,2010, Taylor *et al.*, 2011). Till date, only few studies have investigated penile length in pubertal males with EDCs exposure. In a sample of 55 boys between age 11-14, maternal exposure with PCBs during pregnancy was linked with reduced penile length (Guo *et al.*, 2004). Di Nisio *et al.*,2018 also observed similar findings between 18–19-year teenagers. Their findings suggest that exposure to EDCs can also result in reduced penis size in adolescent.

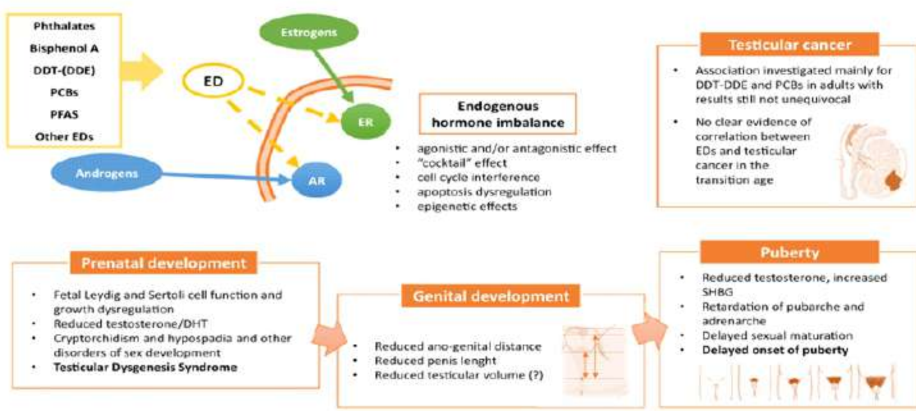

Fig. 2 Endocrine disruptors mechanisms of endogenous hormone imbalance and the adverse consequences on male puberty, genital development, and andrological health. (Adapted from Cargnelutti *et al.*, 2021)

Effects of spent oil on Soil

Soil is a vital non-renewable natural resource and as a habitat, it houses several microorganisms including other higher animals and plants whose activities, wastes and ultimately their remains contribute to soil quality (Sultan *et al.,* 2015). It is a complex natural mixture consisting of water, air, organic matter, mineral nutrients and living organisms whose quality, richness and population size are determine by several environmental factors like climate, parent material, organism type and time of existence (Blott & Pye, 2012). Additives and contaminants like iron, cadmium, copper, dirt, barium, lead, zinc, ash, sulfur, dirt etc are produced as a result of long operation and the various conditions to which the atmosphere and reduce the air quality (Teresa *et al.,* 2005). Other volatile organic compounds (VOCs) present in the disposed spent oil also evaporate to the atmosphere which also result in decline air quality. Not only is the air quality affected, it also results in other grave consequences like acid rain which have destroyed many vegetations, loss of some lower animals, destruction of monumental structures like statutes, corrosion, increased pH of streams and rivers and ultimate loss of some aquatic animals either through migration or death for those that cannot survive under such severity.

Effects of spent oil on Aquatic ecosystem

Being central to survival serving various purposes such as source of drinking water for man and animals, habitat for aquatic animals and plants, cooling center for some fatty animals that cannot withstand high temperature, source of food for various birds, irrigation source for farmlands etc, the healthy state of rivers, streams and lake is a collective effort. Upon disposal in open soil, oil can percolate into water bodies (Olugboji & Ogunwole, 2008) thereby altering the normal balance action of the water. The contamination of groundwater arises when oil absorbed through soil layers find their ways into lakes, streams and rivers. Its effects on aquatic lives are far reaching mainly from the formation of oily film on the water surface which reduces the amount of oxygen dissolved in the water bodies needed by fish and other aquatic organisms that make up the food chain. Being mostly in motion as it flows from place to place, the pollution effects are not limited to pollution source alone or to the living organisms in the pollution source. This also should remind us that the safety of our rivers and coastlines is a necessity.

The effects produced by water contaminated with spent oil range from mild symptoms to complete impairment of body functions and even death of aquatic lives as a result accumulation of toxic compounds in the liver (Noln *et al.*, 1990). The aquatic environment is a complex form of interaction involving plants, animals and their physical environment. Any stress, distortion, disruption or harm experienced by the environment will produce similar effect on one or more of the living forms either plant or animal. Subsequently, this effect will also be felt by other organisms that depend on them directly for food and if not checked, the entire food chain might be compromised.

The effects of water contaminated with spent oil or spill will determine where the organism resides; in the open water, near the coastal areas or on the shorelines. Higher aquatic animals like whales, sharks, etc have the capacity to swim away from spill source by going deeper or further out to sea, and as such, the possibility of being affected by major spill is reduced. Some, however live very close to shorelines including seals, dolphins, turtles etc and are prone to contamination from the oil that washes onto beaches or through the consumption of oil-stained prey. Other species which depend on kelp beds and sea grasses for their shelter, hatching, food and nesting sites also suffer contamination as a result of oil pollution particularly in shallow waters.

EDCs effects

Some of these pollutants have been reported to have negative effects on the endocrine gland and hence are termed endocrine disruptors (EDs). Studies have reported the negative effects of EDCs on reproductive system of aquatic lives. The first case of EDCs in fish species in Africa involved intersex in the African catfish (*Clarias gariepinus*) found in water sources that has been contaminated with the estrogen compound p-nonylphenol (p-NP) whose sources has been suspected to be from nearby industrial and agricultural lubricating oil in the engine is exposed. The disposal of such spent oil can be more environmentally damaging (Abioye *et al.,* 2014) when these contaminants and additives find their way to the environment through water ways, soil or air. They are capable of producing both short- and long-term effects (Hadi, 2023).

The direct disposal of spent lubricating oil on open land can result in population reduction and possible loss of microorganism biodiversity (Aina *et al.*, 2009) and as a consequence, soil quality suffers (Subin *et al.,* 2015). In order to correct this anomaly, particularly where such soil is to be used for agricultural purposes like planting, fertilizers may be applied as a source of nutrient enhancement and where there is runoff, nearby rivers and streams receive part and so suffers contamination and possible eutrophication. Thus, on global scale, soil degradation hinders economic growth and environmental quality (Censi *et al.*, 2006).

The direct and accidental discharge of lubricants, grease, solvents and other oil-based products on land, most of which are petroleum based are highly toxic and hazardous to soil organisms and man. Spent lube oil being less viscous than fresh virgin oil as a result of breakdown of additive properties, when disposed into soil, adhere to soil particles, reduces percolation and soil aeration (Mocek *et al.,* 2012, Warmate *et al.*, 2011).

Additionally, soil polluted with spent oil have increased PAHs concentrations, heavy metal contents which if not controlled or well managed could result in poor plant growth, low yield and source of various human diseases as these hazardous substances could find their way to human via food chain. Though some of these metals could serve as essential micronutrients for plants when present in low concentrations but at higher concentrations, many plants experience stunted growth and metabolic problems ((Achuba & Peretiemo, 2007, Adelekan *et al.*, 2015).

Depending on the circumstance, the chemicals in mineral-based crankcase oil exhibit different features within the environment. Soils polluted with spent lubricating oil were found to have decreased texture (Akoachere *et al.,* 2008). In the studies of (Achuba and Peretiemo, 2007), it was revealed that seed germination and plant growth were adversely deterred as a result of soil catalase inhibition caused by spent oil. The soil temperature is also believed to be highly affected as a result of the disposed spent oil. For instance, (Raven *et al.*, 2005) posited that soil polluted with spent oil has the capacity of achieving temperature range of 65-70°C which is often detrimental to plants growth compared to 24 - 32°C as the maximum required temperature for ideal plant performance. When the effects of soil polluted with left over cooking oil were studied on tomato and pepper plants, it was observed that tomato was adversely affected than pepper (Anoliefo & Vwioko, 1995). In a similar report, spinach growth rate was studied on soil polluted with spent oil and it was reported that the germination rate was very poor, the chlorophyl and seedling's protein were also adversely affected (Odjegba & Idowu, 2002)

Effects of spent oil on air quality

Air quality is essential to all living creatures particularly humans as the purity of the oxygen needed for various vital biochemical reactions within the human systems should not be compromised. The poor management of spent oil and the various applications of it including burning in incinerators, fuel in boilers, in cement kilns, leakages, spills, incomplete combustion and combustion of leaded fuels. Contaminants like lead, chromium, zinc, oxides of nitrogen, oxides of sulphur, from these sources enter into the activities and also possibly from municipal treatment plants (Barnhoorn *et al.*, 2004). For instance, EDCs have been found to be responsible for the thinning of waterbird eggs (Bouwman *et al.*, 2008, Bouwman *et al.*, 2013). Increase in the concentration of these contaminants have also been directly linked to eggshell thickening of the Nile Crocodile eggs (Bouwman *et al.*, 2014). These effects pose a serious threat to the successful succession of these animals. Within the South African estuary, high concentration of lead, mercury, arsenic and cadmium were detected in the juvenile stages of the angling fishes *Argyrosomus japonicus, and Pomadasys commersonnii* (Nel *et al.*, 2015). Some of these pollutants were detected at high concentrations exceeding the recommendation limit of international food quality guidelines particularly cadmium and arsenic. EDCs have also been found in African penguin eggs (Bouwman *et al.*, 2015).

Effects of spent oil on Avian

Though of flight mode, they are migratory in nature and most derive their food directly from aquatic environment while some spend their lifetime around the seaside like the penguins. Based on exposure, an oil-stained bird can experience series of effects varying from short to long-term including poor health, plumage damage, delayed migration, reproductive impairment and even death in severe cases (Henkel *et al.,* 2012, DHNDAT, 2016). Other effects produced by oil contamination are poor homeostasis, breathing problems, damage to blood cells and other internal organs, reduced population among others.

As the impact of spent oil or oil spill on bird are numerous, it is therefore important to examine the various routes of exposure to better understand their susceptibility and the best rescue mission that could be proffered in the immediate. Birds are usually exposed to oil contamination through multiple routes like feathers, skin, mouth and through their food.

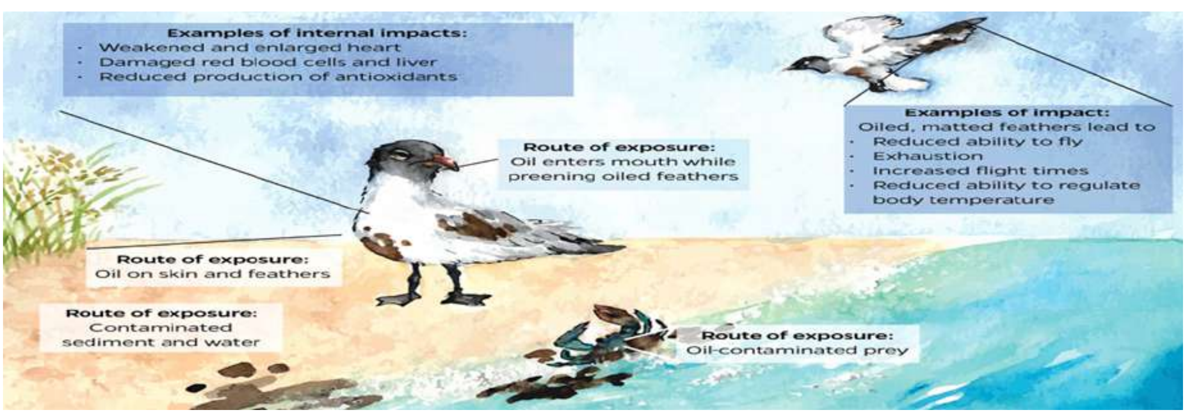

Fig. 3 Adapted from: Maung-Douglass *et al.,* (2019): Birds of Feather – Coping with Oil
The fate of the oil-stained birds as determined by the impacts from various routes of exposure is enumerated below.

Effect on Plumage

Healthy state and temperature balance is central to the upmost survival of birds to which the plumage ensures and regulates. Aside these roles, other vital functions which the plumage performs includes colorful display leading to mate attraction, flight support system, buoyancy support and insulating medium. When birds are exposed to oil, their feather becomes matted down and this result to loss of insulating property of the feather with attendant inability to maintain stable temperature and possible freezing (Jenssen, 1994). This also put the birds at greater risk of drowning while hunting in open water as the delicate structure of their feathers that allows for flight and buoyancy becomes affected. In contrast with their unstained counterparts, oil-stained birds spend more time preening their feathers with their beaks in bits to ensure it is straightened and clean. The time spent performing this task seems to be a waste as it could be used for other vital activities that will ensure overall health and survival like resting, foraging and reproduction (Jenssen, 1994). Birds can also ingest oil while preening and this could lead to lethal implications (Pritsos *et a*l., 2017).

Effect on Migration pattern

Seasonal migration is among the courtship behaviors displayed by birds either for mate, food, nesting or for safety reasons. As a result of constant motion of streams and rivers, oil polluted waters have the potential of affecting birds in far distance areas outside the pollution source. For predictable reasons, migratory birds travel long distance either to nest, mate, feed or to escape the prevailing climatic condition. The success of this exercise depends on the overall health status of the birds. Oil-stained birds often experience challenges while flying. Aside the exhaustion experienced, oil-stained birds could also be out of the regular migration season (Perez *et al.*, 2017).

In order to understand the effect of oil stain on migratory birds, Perez *et al.*, (2017) conducted studies on homing pigeons. Like migratory birds, homing pigeons were preferred because they can travel long distances and by practice, return to their human handlers. It was observed that lightly oil-stained homing pigeons spent more hours before returning home unlike the unstained counterparts. It was also observed that while many of the unstained homing pigeon birds could complete their flight without stopping, the oil-stained birds spent about 50% of their flight time resting as a result of exhaustion. Perez *et al.,*2017 explained that feathers that are matted with oil are less aerodynamic and this often cause difficulty while flying.

Maggini *et al.,* 2017 also found that oil-stained sandpipers have less wingbeat power compared to the unstained birds. Slower take-off time is also experienced with birds that are lightly oil-stained in comparison with the unstained birds and this subjects them to predatory attacks. Those that can still fly form part of the food webs in various locations (Henkel *et al.*, 2012). While hunting for their daily meal, oil-stained birds are also exposed to danger of being eaten by other predators and when this happen, there is introduction of oil into the food web that is not directly affected by oil spill (Zuberogoitia *et al.*, 2006). Again, unstained migratory bird may be exposed to oil when they migrate to oil polluted habitats and ingest preys that are oil-stained or get stained while searching for food (McCann *et a*l., 2017) and this can produce grave consequences. For example, in Louisiana saltmarshes, majority of the resident birds are migratory in nature and this includes the likes of wading birds, terns, gulls etc and are in close relationship with many animals and plants in the marsh (Zuberogoitia *et al.*, 2006). These birds were described to be highly sensitive to oil spill and because of their close relationship with other animals and plants in the marsh, any negative effects on them could distort the association balance between them and other life forms in the marsh.

To address this menace, several rescue campaigns and practices have been explored including cleaning the oil-stained birds with detergent particularly in major oil spills.

However, the survival rate of these birds varies when they are eventually released to the wild (Henkel & Ziccardi, 2017) and this depends on several factors like the specie affected, the stress caused, the cleaning techniques employed and the condition of the spill (Henkel & Ziccardi, 2017).

It was observed that the survival of oil-stained birds after cleaning, rehabilitation and release is often compromised. For example, the Murres rehabilitated from the several spills experienced between 1969 to 1994 including the likes of Exxon Valdez only lived a week after the clean-up exercise (Sharp, 1996). Recent studies however showed that oil-stained birds in other spills e.g pelicans, gulls, gannets and penguins displayed post-rehabilitation survival rate in close correlation with unstained birds (Henkel & Ziccardi, 2017).

Among the factors affecting the post-rehabilitation survival rate, the drying time for plumage gained more attention during the cleaning techniques (Jenssen, 1994). Until when the plumage is fully dried, the protective and insulating oil of a bird's skin and feather is not fully felt (Jenssen and Ekker, 1989). The survival rate of sea Otters was increased during post-rehabilitation when the drying period for their feathers was extended to a week and the naturally protective and insulating oil of the skin was returned in contrast with Otters that were immediately released after cleaning with attendant high mortality (Jenssen, 1994).

Effects of Chronic Oiling

The continued succession of any specie group is hinged on the survival rate of the young ones and the rate of reproduction of the older group. Sea side sparrows on the coastal wetlands of the Gulf of Mexico displayed this behavior. It was discovered that these birds exhibited slow reproduction after few years of the Deepwater Horizon oil spill of 2010 compared to previous years (Bergeon *et al.*, 2014). A reasonable suggestion for this could be the death of most of the plant species which the birds often used for nesting purposes as a result of pollution. Aside this, other suggestions could also be the ingestion of oil-stained prey on which the birds fed (Bonisoli *et al.*, 2016). In other studies, conducted on mallard Ducks, the toxic effects were examined on chicks developing eggs that were oil-stained as a result of exposure. It was observed that the oil-stained eggs have less tendency to hatch (Finch *et al.,* 2011).

The way forward

Understanding the various consequences that come with improper handling of SLOs and the non-renewability nature of its main source, it is important to devise proper management methods for this crucial product. Ayadi & Ayedun, 2024 explored the various recovery techniques for SLOs, bridging the gaps between the conventional and modern methods while highlighting their merits and shortcomings. Among the various options explored, the recovery method is the most canvassed and this has received series of attentions from various scholarly publications where various materials have been utilized to ensure maximum recovery yield while considering environmental health. Clays, acids, solvents, activated carbon, polymer membranes etc. in various formulations under varied experimental conditions have been investigated and reported to which the literatures lend endless credence. The solvent method has been found to be very effective in achieving high recovery yield up to 70-75% with solvent recovery rate of about 95% using 3:1 solvent to oil ratio (Pai *et al.*, 2016). Abdulaziz & Mahmood (2016) also reported the synergistic potency of composite solvents producing oil and solvent recovery of 93.7% and 96.2% at 4:1 solvent to oil ratio. The findings of Hussein &

Abdulkarim (2016) also support the effectiveness of solvent method of spent oil recovery where 88.88% recovery rate was reported with enhanced physicochemical parameters.

Other recovery methods in cases of spill are the use of mechanical containment utilizing skimmers, booms and sorbents to the oil from water surface. Also of importance are the dispersing agents and biological agents like enzymes and microorganisms which accelerate the natural biodegradation actions. In enhancing biodegradation actions, bioremediation techniques like bioaugmentation and biostimulation can also be explored. In-situ burning can also serve as a recovery and clean up method, though with certain shortcomings, might be an efficient cleanup method given that few negative effects will be felt by man and the environment. For maximum efficiency, it is often used with mechanical recovery methods.

Conclusion

The effects of spent oil on man are innumerable affecting practically all resources upon which the survival of man depends i.e the air, water, soil, fish, animals, birds etc. It is therefore imperative that urgent attention be given to the proper management of spent oil. Its recovery will also reduce pressure on the crude reserves. Aside reducing the high cost of virgin oil purchase, recovery also serves as an avenue for job opportunities as the environment gets less pollution source. Strict policies should also be enacted to curb the indiscriminate disposal while education and enlightenment programs should be prioritized on the need for proper management practices by highlighting the inherent dangers of careless disposal, cost of clean-up, cost and energy demands for virgin oil production and the continued depletion of crude reserves.

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