Article

Simplified Procedures for Managing Insecticidal Wastes; A Case of KCMUCo-PAMVERC Vector Control Product Testing Facility in North-Eastern Tanzania

Agness Msapalla[1,2], Salum Azizi[1,2*], Menan Jangu[3], Njelembo J. Mbewe[2,4], Johnson Matowo[1,2], Magreth Shayo[1,2], Robert Kaaya[1,2], Benson Mawa[1,2], Amandus Joram[1,2], Matty J. Kirby[2,4], Mark W. Rowland[2,4] and Franklin Mosha[1,2]

1 Department of Medical Parasitology and Entomology, Kilimanjaro Christian Medical University College, Moshi, P.O. Box 2240, Moshi, Tanzania.
2 Pan African Malaria Vector Research Consortium (PAMVERC), Moshi, 255, Tanzania.
3 National Environment Management Council, P.O.BOX 63154, Dar es salaam, Tanzania
4 Department of Disease Control, London School of Hygiene and Tropical Medicine, WC1E 7HT, UK.
* Correspondence: salum.azizi@gmail.com

Abstract: Insecticide testing facilities that evaluate a variety of vector control products may generate large amount of hazardous wastes from routine operations. These wastes originate from degraded technical grade materials, sprayed substrates, redundant stock or working insecticidal solutions. The washing of Long-Lasting Insecticidal Nets (LLINs) during preparation for laboratory and experimental hut trials also contribute to waste water with insecticide content. Human and environmental exposure to insecticidal waste can occur during transport, categorization, storage and disposal in resulting in environmental pollution and potential health effects. Various national and international guidelines have been devised for safe disposal and should be strictly followed to avoid adverse effects on humans or environment. The current paper describes a case study from insecticide test facility in north-eastern Tanzania in management of insecticidal waste.

Keywords: insecticidal wastes, waste disposal, incineration, waste pit, environment, testing facility, climate

1. Introduction

Malaria control and prevention relies on the use of insecticides in the form of treated bed nets or residual spraying in households [1,2]. The problem of increased insecticide resistance in vectors, inspires innovation in alternative insecticide which in turn inspires innovation of assessment procedure until final registration for public health use [3]. During this process, every stage of pesticide evaluation from storage to use and equipment cleanup generates waste [4].

Despite deficiencies in the legislative and regulatory frameworks for public health pesticides among WHO member states in countries with high burden of vector borne diseases [5,6], there is a steady increase in pesticide importation and use in East Africa [6]. For example, in Tanzania, 2500 tons of agricultural and public health use pesticides were imported in 2003 compared to only 500 tons in 2000, with 18% of total imported pesticides dedicated for public health [6,7]. Exposure to insecticides and its wastes has been shown to cause both adverse effects to human health [8,9] and the environment [10,11]. Prior to 1990, there was no systematic guidelines for disposal of insecticide-contaminated wastes [4]. In the 1990s, the Commission on Agrochemicals and the Environment, later renamed the Advisory Committee on Crop Protection Chemistry, within the Division of Chemistry under the Environment of the International Union of Pure and Applied Chemistry (IUPAC) initiated a critical analysis of strategies and methods for disposal of pesticide-contaminated wastes [4,10]. Among the key objectives of this analysis was to explain practicability of waste disposal technologies recommended for small waste generators which

 doi:10.20944/preprints202203.0159.v1

could not afford sophisticated technologies. Most of the test facilities that evaluate different vector control insecticidal products falls under small waste generators category.

Most of the procedures recommended for waste reduction, and disposal in the Food and Agriculture Organization documents [12,13] and other researchers[4] are at large recommended by Tanzania's National Environmental Management Council (NEMC) [14,15]. However, most facilities still lack capacity to analyze and characterize wastes to facilitate safe and appropriate disposal e.g. by gas or high-pressure liquid chromatographs. A relatively cheap technique for characterization, thin layer chromatography (TLC), which is considered suitable for testing facilities in developing countries still requires expensive purified organic solvents that makes the option prohibitive. As a result, the Kilimanjaro Christian Medical University College-Pan African Malaria Vector Research Consortium (KCMUCo-PAMVERC) in Tanzania has relied on NEMC inspection for waste characterization and disposal advice. The NEMC is mandated under the Tanzanian Environmental Management Act (EMA) Cap.191 of 2004 to oversee environmental management issues and implements the resolutions of the Stockholm declaration [16] at national level. Relevant national legislation and Acts of Government are also closely followed. This paper describes a case of insecticides testing facility, KCMUCo-PAMVERC in northern-eastern Tanzania where different technologies, national and international guidelines have been adopted.

2. Key policies and guidelines availability for insecticidal waste management

2.1. Identifying national and international policies and guidelines

KCMUCo-PAMVERC test facility, through its management and health & safety committee reviewed available international policies that provide guidance in all aspects of pesticide handling, formulation, import and export, registration and disposal [7] such as Tropical Pesticides Research Institute Act No 18, 1979, the Pesticides Control Regulations -1984, Plant Protection Act (1997), and Plant Protection Regulation (1999). These policies were then translated and converted to facility's SOPs on chemical usage and waste management.

2.2. Requesting insecticidal waste management guidelines

The facility contacted the NEMC, under its Chemical Advisory Committee (CMAC), to oversee the management of chemicals, perform inspection, and provide an inspection report which could be used as a guidance.

3. Procedures for insecticidal waste management

3.1. Study site

Kilimanjaro Christian Medical University College Pan African Malaria Vector Research Consortium (KCMUCo-PAMVERC) is one of the test facilities in Tanzania that evaluates insecticides for public health use (17). The KCMUCo-PAMVERC is located in Kilimanjaro region, Noth-western Tanzania, and has its insecticide testing facilities at Moshi urban (Longuo B), Pasua and Mabogini (Figure1). It is the first African vector control test facility to achieve the Organization for Economic Co-operation and Development principles of Good Laboratory Practice (OECD-GLP) accreditation (18).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 11 March 2022 doi:10.20944/preprints202203.0159.v1

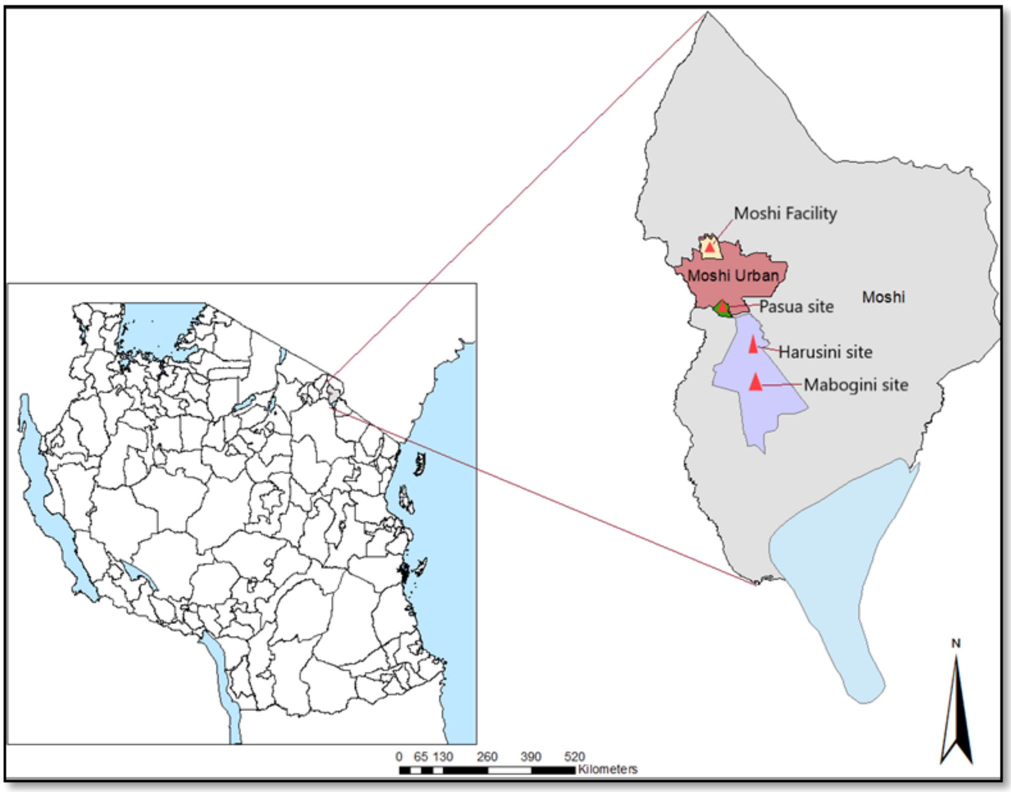

Figure 1. A map of Tanzania indicating the KCMUCo-PAMVERC sites related to insecticide testing.

3.2. Facility inspection by national authority

To comply with above requirements, KCMUCo-PAMVERC Test Facility consulted the NEMC for chemical waste inspection and guidance on the management and disposal of its obsolete pesticides, pesticide-contaminated wastes and other chemical reagents at its premises. This is in line with the OECD-GLP document (19) which encourages facilities to comply with national requirements for the disposal of chemicals and biological products. The NEMC assessment was based on the type, quality and quantities of pesticides eligible for disposal. The storage conditions, packaging materials and labels were also assessed. Furthermore, other pertinent information on disposal recommendations was reviewed.

3.3. Identifying waste generation points and developing a management plan

After the inspection, NEMC-CMAC suggested the use of standardized incinerators for the disposal of solid chemical wastes and waste pit for the hazardous liquid chemical waste. NEMC provided PAMVERC with a blueprint for waste pit construction. From the NEMC inspection report and blueprint, KCMUCo-PAMVERC has been able to identify all sources that generates waste and drawn a management plan as indicated in **Figure 2**.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 11 March 2022 doi:10.20944/preprints202203.0159.v1

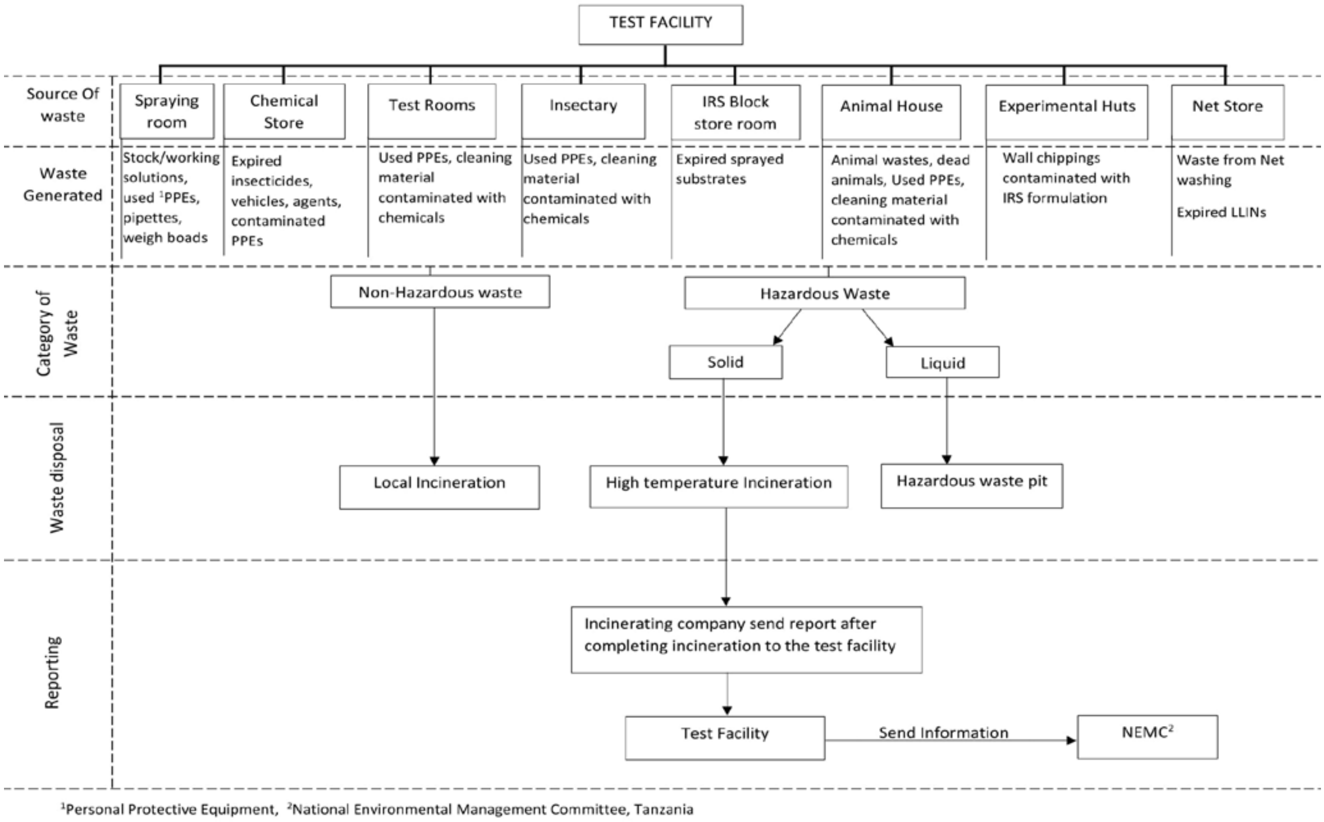

Figure 2. Test facility waste management pathway.

3.4. Categorization of wastes generated

Depending on the type of waste, different disposal procedures apply. At the KCMUCo-PAMVERC Test Facility wastes have been categorized into hazardous and non-hazardous (normal) waste. Hazardous wastes have been further categorized into liquid and solid hazardous waste. The liquid waste includes: obsolete technical grade insecticidal formulations, novel insecticide formulations, vehicles (solvents), reagents, cleaning solutions (10% bleach and 70% ethanol), water from net washing, insecticide residue from compressional spray tanks, waste solutions from cleaning the Potter Spray Tower (Burkard Scientific, England), used for spraying 10cm diameter blocks of various materials.

The solid hazardous wastes include technical grade insecticidal formulations, novel insecticide formulations, insecticide-treated test papers, insecticide-treated substrates, insecticide-treated wall chippings from indoor residual spraying hut trials, insecticide-sprayed materials such as plastic sheets and hessian, LLINs and dipped nets (whole nets and net pieces), insecticide-contaminated consumables (including expired/used Personal Protective Equipment, metallic spare parts of spraying equipments) and sharps. Non-hazardous wastes from insectaries, laboratories, offices and field station are collected and incinerated in our locally built incinerator. They include obsolete non-chemical materials.

3.5. Waste packaging and containment

Various containment measures have been established to prevent hazardous waste leaking into the environment or human exposures. Apart from environmental risk assessment of the hazardous waste pits which is recommended by NEMC-CMAC, solid waste is stored in intact and leak-proof containers within a restricted entry enclosure protected from rain. These enclosures have been reinforced with wire mesh to prevent small reptiles from reaching the enclosure.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 11 March 2022 doi:10.20944/preprints202203.0159.v1

Wall chippings are packed into special bags (with 2 bags; outer polypropylene bag and inner multi-layered hermetic bag) and labelled with insecticide name, concentration, technician name and date of collection and transportation to the temporary storage site situated at Harusini field site in Lower Moshi until the scheduled date of transportation to disposal. Special cabinets - Armorgard FlamStor Cabinet™ (Armorgard Ltd, Unit 14-16 Standard Way, Fareham Industrial Park, Fareham, Hampshire, PO16 8XB, United Kingdom) are used for keeping hazardous substances safe, organised and accessible with the specially designed flameproof vents to prevent build-up of fumes.

3.6. Implementation of solid and liquid hazardous chemical wastes disposal

KCMUCo-PAMVERC insecticide testing facility identified and contracted an independent company for incinerating the hazardous solid waste incineration. The incineration temperature is high enough to burn insecticides into smoke-nil combustion gases that are similar to those generated by wood burning (4). Insecticide incineration at lower temperatures is not recommended as it tends to produce toxic intermediate products (20). To be able to transport the chemical wastes, a NEMC registered transporting company was contracted that meets all requirements for transporting hazardous materials (21). As for the hazardous liquid chemical waste disposal, the facility contracted construction company to build the waste pit for liquid waste disposal based on the NEMC blueprint (**Figure 3 and 4**). The structure presents a mechanism similar to that used for carbon-adsorption treatment of pesticide containing wastewater (22).

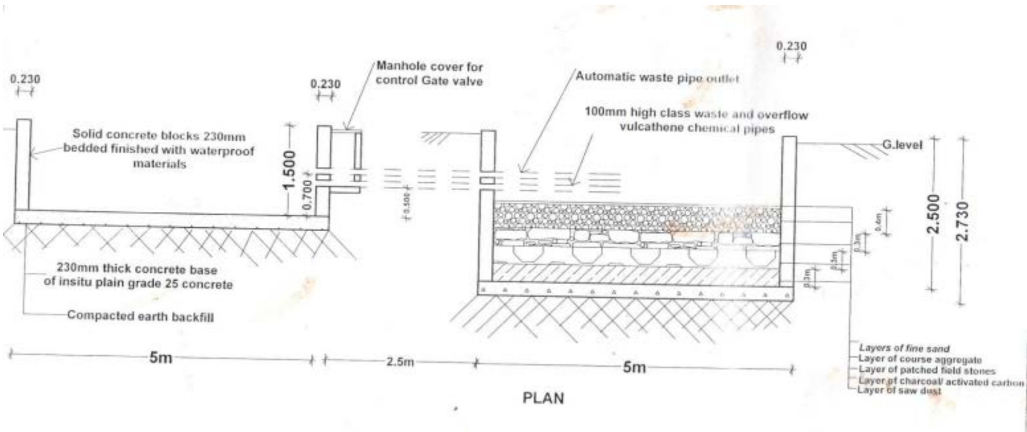

Figure 3. Hazardous waste pit schematic blueprint (NEMC).

Figure 4. A picture of constructed waste pit at KCMUCo-PAMVERC, Tanzania.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 11 March 2022 doi:10.20944/preprints202203.0159.v1

The non-hazardous waste is collected routinely and incinerated in a local constructed incinerator (**Figure 5**).

Figure 5. A locally constructed incinerator at KCMUCo-PAMVERC.

3.7. Internal monitoring for waste management

The facility established the Health and Safety Committee to oversee operations. The committee provides training on laboratory safety rules, organizes annual waste disposal, reports and responds to non-conformance incidents, any accidents and emergencies. It also performs the quarterly and annual risk assessments for study related procedures and routine facility operations.

3.8. Training and internal guidelines

The facility identified appropriate mandatory training including chemical handling for the Health and Safety Committee members and department members who are involved with handling of chemicals (**Figure 6**). The trainings are offered by the Tanzania Occupational Safety and Health Authority and Tanzania Plant Health and Pesticides Authority.

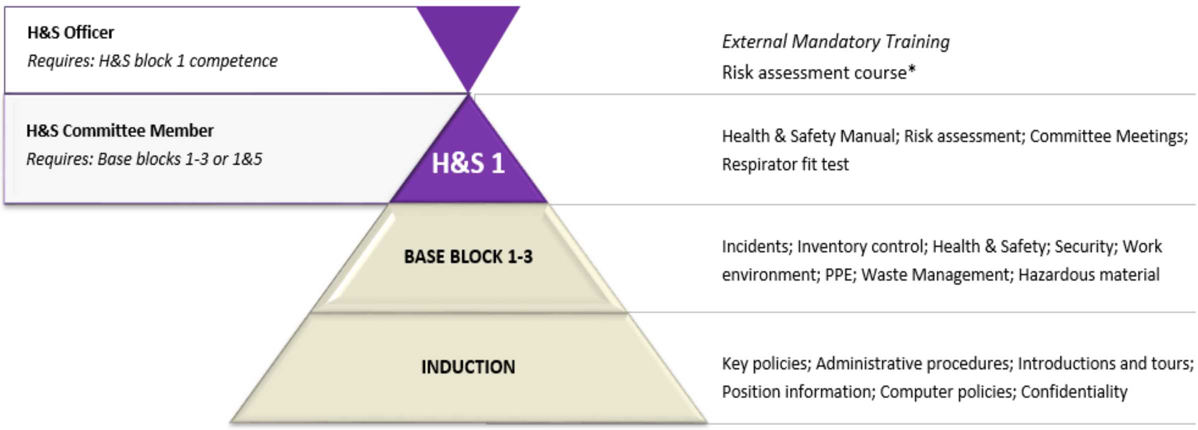

Figure 6. Training pathway for the Health & Safety committee members.

Similarly, all staff who handle chemicals, undergo mandatory training that covers training in safe use and disposal of chemicals. Additionally, specific waste disposal Standard Operating Procedures (SOPs), safety manual as well as simplified guidelines for internal use have been generated for proper management of facility wastes. The test facility staffs have been trained and assessed on annually for their competence.

4. Challenges

4.1. Waste disposal expenses

High costs related to waste package, transportation and incineration are experienced. Waste coming from experimental huts chippings requires large number (>300) of special double layer bags per one site, the cost of each bag being approximately 5 dollars, while waste transportation and incineration costs are approximately 3,500 dollars per year. However, transport cost is directly related to waste bulkiness and distance from the collection point to the incineration point. This type of challenge in Africa is too large and has triggered the Food and Agriculture Organization to request major chemical industries to collaborate in clean-up and disposal of obsolete pesticides (20).

4.2. Disposal of new insecticides or mixtures

The new classes of insecticides or formulations require++ a separate inspection and guidance from national authorities. The new paradigm of vector control that is based on the use of insecticide mixtures presents new challenges in determining effective disposal (4). The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusions

Simple, safe and effective management of insecticidal waste is not only a legal necessity but also a social responsibility to ensure human and environment health are not negatively affected. This paper outlined simple but safe practices derived from international and national guidelines that can be adopted by other similar facilities.

Lack of concern, motivation, awareness and high costs are some of the problems that may impact upon good waste management (23,24). Thorough inspections of waste generation and management caused by insecticidal testing facilities are paramount.

Facilities must make concerted effort to ensure that the obsolete and or unwanted pesticides are properly managed. This includes collection, segregation, containment, transport, risk assessment and disposal. Judicious and minimal procurement and use of insecticides means less waste generated, less cost for disposal, a safer working environment and more efficient waste disposal systems. To ensure sustainability, ffacilities should introduce and apply practices which reduce costs related to waste management and disposal but not at the expense of human population safety and the environment, which are of paramount importance. The government should advocate more environmental friendly insecticide waste disposal, such as combining incineration with energy recovery technology to offset fossil fuel usage and the associated CO_2 emissions or build capacity for biodegradation of insecticidal waste(25,26).

Author Contributions: "Conceptualization, A.M, S.A.,M.K. and F.M.; methodology, A.M, S.A.,M.K. and F.M.; investigation, A.M, S.A.,M.K., M.R and F.M.; resources, A.M, S.A.,M.K. and F.M.; writing—original draft preparation, S.A. and A.M; writing—review and editing, A.M, S.A.,M.K., J.M., N.J.M., M.S., M.J., R.K., B.M., A.J., MR. and F.M.; supervision, J.M., M.R. and F.M.; project administration, A.M., S.A. and M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: We thanks the whole team at the KCMUCo-PAMVERC for their invaluable contribution to this this study. We also thank the KCMUCo and KCMUCo PAMVERC in particular for allowing us to do research using their facility and resources.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lengeler, C. "Insecticide-treated bed nets and curtains for preventing malaria." *The Cochrane database of systematic reviews* ,2 (2004): CD000363. doi:10.1002/14651858.CD000363.pub2
2. Pluess, Bianca et al. "Indoor residual spraying for preventing malaria." *The Cochrane database of systematic reviews* vol. 2010,4 CD006657. 14 Apr. 2010, doi:10.1002/14651858.CD006657.pub2
3. Lees, R., Praulins, G., Davies, R. et al. "A testing cascade to identify repurposed insecticides for next-generation vector control tools: screening a panel of chemistries with novel modes of action against a malaria vector." *Gates open research* vol. 3 1464. 10 Jul. 2019, doi:10.12688/gatesopenres.12957.2
4. Felsot, Allan S et al. "Disposal and degradation of pesticide waste." *Reviews of environmental contamination and toxicology* vol. 177 (2003): 123-200. doi:10.1007/0-387-21725-8_3
5. Matthews, Graham et al. "Status of legislation and regulatory control of public health pesticides in countries endemic with or at risk of major vector-borne diseases." *Environmental health perspectives* vol. 119,11 (2011): 1517-22. doi:10.1289/ehp.1103637
6. Loha, Kumelachew Mulu, et al. "Import, Disposal, and Health Impacts of Pesticides in the East Africa Rift(EAR) Zone: A Review on Management and Policy Analysis." Crop Protection, vol. 112, 2018, pp. 322–31. Crossref, https://doi.org/10.1016/j.cropro.2018.06.014.
7. Agenda. A Case Study on Trade and Utilization of Pesticides in Tanzania: Implication to Stockpiling. Final Report, Dar-es-Salaam, Tanzania. Dar es Salaam; 2006.
8. Aktar, Md Wasim et al. "Impact of pesticides use in agriculture: their benefits and hazards." *Interdisciplinary toxicology* vol. 2,1 (2009): 1-12. doi:10.2478/v10102-009-0001-7
9. Bradberry, S.M., Cage, S.A., Proudfoot, A.T. *et al.* Poisoning due to Pyrethroids. *Toxicol Rev* **24,** 93–106 (2005). https://doi.org/10.2165/00139709-200524020-00003
10. Ware G. *Reviews of Environmental Contamination and Toxicology: Continuation of Residue Reviews 1990th Edition*. New York, NY: Springer, 1989.
11. Antwi, Frank B., and Gadi V.P. Reddy. "Toxicological Effects Of Pyrethroids On Non-Target Aquatic Insects". *Environmental Toxicology And Pharmacology*, vol 40, no. 3, 2015, pp. 915-923. *Elsevier BV*, https://doi.org/10.1016/j.etap.2015.09.023.
12. "Guidelines On Management Options For Empty Pesticide Containers". *Fao.Org*, 2008, https://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/Containers08.pdf.
13. "Environmental Management Tool Kit for Obsolete Pesticides". *Fao.Org*, 2020, https://www.fao.org/fileadmin/templates/obsolete_pesticides/Guidelines/EMTK4xweb_nov_small.pdf.
14. Malisa, Angela. "SITUATION, CHALLENGES AND PLANS FOR ENVIRONMENT STATISTICS IN TANZANIA". *Unstats.Un.Org*, 2007, https://unstats.un.org/unsd/ENVIRONMENT/envpdf/UNSD_UNEP_ECA%20Workshop/Tanzania.pdf.

15. NEMC. THE NATIONAL ENVIRONMENTAL RESEARCH AGENDA FOR TANZANIA 2017-2022. 2017. Available from: https://www.nemc.or.tz/uploads/publications/sw-1576226565-The National Environmental Research Agenda for Tanzania 2017 - 2022.pdf

16. "United Nations Conference on Environment and Development: Rio Declaration on Environment and Development.". Vol 31, no. 4, 1992, pp. 874-880. *Cambridge University Press (CUP)*, https://doi.org/10.1017/s0020782900014765.
17. College-PAMVERC KCMU. Pan-African Malaria Vector Research Consortium (PAMVERC) [Internet]. 2021. Available from: https://pamverc.or.tz/indexs.php?pamvercdataset=pamverc_research

18. Begg, Sara et al. "Developing Laboratory Capacity for Good Laboratory Practice Certification: Lessons from A Tanzanian Insecticide Testing Facility". *Gates Open Research*, vol 4, 2020, p. 59. *F1000 Research Ltd*, https://doi.org/10.12688/gatesopenres.13133.1.

19. "OECD Series on Principles Of Good Laboratory Practice (GLP) And Compliance Monitoring - OECD". *Oecd.Org*, 2022, https://www.oecd.org/chemicalsafety/testing/oecdseriesonprinciplesofgoodlaboratorypracticeglpandcompliance-monitoring.htm.

20. Kennedy, M.V., Stojanovic, B.J. and Shuman, F.L. Jr. Chemical and thermal methods for disposal of pesticides. Residue Rev. 1969;29:89-104. doi: 10.1007/978-1-4615-8455-1_8. PMID: 4900809.

21. Leonelli, P., Bovincini, S. and Spadoni, G. "Hazardous Materials Transportation: A Risk-Analysis-Based Routing Methodology". *Journal of Hazardous Materials*, vol 71, no. 1-3, 2000, pp. 283-300. *Elsevier BV*, https://doi.org/10.1016/s0304-3894(99)00084-9.

22. Kämpf, Hartmut J. "Repeated Use of Granular Activated Carbon in Waste Water Treatment". *Water Research*, vol 6, no. 4-5, 1972, pp. 493-494. *Elsevier BV*, https://doi.org/10.1016/0043-1354(72)90137-6.

23. "FAO Requires Financial Support for The Disposal Of Obsolete Pesticides In Africa And The Near East". *Fao.Org*, 2022, https://www.fao.org/NEWS/1998/980307-e.htm.

24. Velzy, C., Feldman, J. and Trichon, M., 1990. Incineration technology for managing biomedical wastes. *Waste Management & Research*, 8(4), pp.293-298. https://doi.org/ 10.1016/0734-242x(90)90004-7

25. Singh, Brajesh K., and Allan Walker. "Microbial Degradation Of Organophosphorus Compounds". *FEMS Microbiology Reviews*, vol 30, no. 3, 2006, pp. 428-471. *Oxford University Press (OUP)*, https://doi.org/10.1111/j.1574-6976.2006.00018.x.

26. Hlihor, Raluca Maria et al. "Bioremediation: An Overview on Current Practices, Advances, and New Perspectives in Environmental Pollution Treatment." *BioMed research international* vol. 2017 (2017): 6327610. doi:10.1155/2017/6327610