A COMPREHENSIVE ANALYSIS OF CLUSTER SAMPLING VERSUS MULTI-STAGE SAMPLING TECHNIQUES: METHODOLOGIES, APPLICATIONS, AND COMPARATIVE INSIGHTS

Kamalu Ikechukwu Okechi[1], Niyomwungere Francine[2], İlker Etikan[3]

1. Department of Biostatistics, Near East University, Faculty of Medicine, Near East Avenue, 99138, Nicosia, North Cyprus, Mersin 10, Turkey
2. Department of Biostatistics, Near East University, Faculty of Medicine, Near East Avenue, 99138, Nicosia, North Cyprus, Mersin 10, Turkey
3. Department of Biostatistics, Near East University, Faculty of Medicine, Near East Avenue, 99138, Nicosia, North Cyprus, Mersin 10, Turkey

ARTICLE INFO

Key words:
Cluster Sampling, Multi-Stage Sampling, Comparative Analysis, Methodologies, Applications, Healthcare Facilities, Hierarchical Structures, Data Collection, Research Practices

Corresponding author:
Kamalu Ikechukwu Okechi,
Email: ikechukwukamalu8@gmail.com

Vol 02 Issue 01
JAN-MAR 2024

ISSN Online: 2960-2599
ISSN Print: 2960-2580

REVIEW ARTICLE

ABSTRACT

Sampling methods play an important role in research efforts, enabling the selection of representative samples from a population for better research. In this comprehensive review, we examine the methods, advantages, disadvantages, applications, and comparative methods of cluster sampling and multistage sampling. Researchers are provided valuable insights to make appropriate decisions tailored to their research objectives. Cluster sampling consists of dividing a population into dissimilar yet externally comparable clusters, whereas multistage sampling further divides these groups into smaller ones in several ways, allowing for the examination of population structures. We explore the advantages, limitations, and usefulness of these approaches in a variety of fields such as market research, public health, social sciences, environmental studies, and agriculture. From measuring consumer preferences to analyzing disease prevalence, both cluster sampling and multi-stage sampling provide researchers with valuable tools for efficiently collecting data and drawing meaningful conclusions. Drawing from a healthcare facilities dataset in Canada, we propose the application of both techniques and advocate for the utilization of multi-stage sampling because of its ability to examine hierarchical structures that are well embedded in the dataset. Using the Open Database of Health Facilities (ODHF), we show how provinces, cities, and healthcare facilities can be represented hierarchically in multi-stage sampling, providing insight into healthcare facility characteristics , while taking a closer look at hierarchical structures. By thoroughly examining these sampling methods, and applying them to a real-world dataset, we aim to contribute to the advancement of sampling techniques in research practices, ultimately enhancing the reliability and validity of research findings.

INTRODUCTION

In cluster sampling, a population is divided into clusters which in turn are randomly chosen for research and then, from the chosen clusters, random individuals are investigated. The sampling process is less expensive but, as intra-cluster similarity is possible, it may invalidate the generalization of the findings.[1] In contrast, multi-stage sampling takes the concept of cluster sampling of a population and carries this idea through multiple stages of sampling, allowing a sampler to use a series of stages of selection of units, sub-clusters and clusters to investigate complex populations

and sampling structures. Multi-stage sampling is a powerful tool that can be utilized to study a wide variety of characteristics of a population, but in multi-stage sampling the proportionate selection of a set of exchangeable units requires care in the calculation of the appropriate probabilities of selection at each stage.[2]

Cluster sampling and multi-stage sampling each have different characteristics, and the decision between them will depend on the nature of the research goals, the nature of the population being studied, the resources available to implement the sampling process, and logistical issues. An increasing awareness of the strengths and limitations of both techniques is vital for researchers, who must make informed decisions about all aspects of the research process: the nature of the sampling design, an estimate of the required sample size, and the nature of the statistical analysis to be applied. These two approaches are widely applied in a range of contexts, including public health, the social sciences and economics – cluster sampling in estimating the prevalence and risk factors for disease, and multi-stage sampling in general population surveys and market research.[3]

Although cluster sampling and multistage sampling differ from each other, they both share similar problems such as the quality of the sampling frame, the number that is needed to select from each cluster, and the inferences that can be made, and tackling these problems requires planning, proper use of established sampling protocols and suitable statistical techniques so that research results can be convincing.[4] Overall, cluster sampling has become quite popular in mainstream sociological research.

The researcher needs to put the available literature together with empirical experiences in order to acquire a theoretical understanding of the advantages and disadvantages of these methodologies, as well as their comparative or relative strengths. In general, such methodological decisions will lead to empirical improvements, consequently advancing sampling techniques, and enhancing evidenced-based research practices. This study aims at explaining the methodological complexities of cluster and multi-stage sampling, and will also provide practical instructions for their use and methodological development to enhance this research tool. By exploring the applications of those sampling techniques in the real world and different theoretical frameworks, this assay intends to contribute to the methodological advancements on sampling techniques and further enhance the rigorousness of empirical research.

Cluster Sampling

Cluster sampling is a method used in sampling, where a population is segmented into clusters or groups.[5] These clusters are then randomly chosen to form the complete sample group for a study conducted by researchers. This sampling approach proves beneficial when researchers aim to survey a widely scattered, extensive population, where sampling each individual is either expensive or unfeasible. Additionally, it is advantageous in scenarios where there exists an inherent clustering or natural grouping within the population, such as households, schools, or neighborhoods.

In this sampling approach, researchers categorize the population into clusters, which are internally diverse yet externally similar subsets. These clusters exhibit external homogeneity due to their shared charac-teristics or criteria but display internal hetero-geneity because the subgroups within each cluster possess varying compositions. Clusters can represent distinct cities within a country, various zones within a city, separate organiz-

ations, different universities, disparate industrial estates, and so on. Once these clusters are identified, researchers choose specific ones for inclusion while excluding the remaining clusters.[6]

Cluster sampling comprises dividing a population into distinct clusters. As it is often unfeasible to encompass all clusters, a random selection method is utilized to choose particular clusters that will represent the entire cluster set. Consequently, all elements within the selected clusters are included in the sample.[7] It is important to note that units from clusters not chosen are not part of the sample, as representation is solely achieved through the selected clusters. For instance, consider a scenario where a team of researchers is investigating rural communities within a state. Employing a simple random sampling method would necessitate visiting each of these communities merely to gather a few subjects from each location, a process that could prove both expensive and time-consuming. Alternatively, they could categorize the rural communities into similar groups and select a random sample of these communities to concentrate their efforts. This approach eliminates the need to traverse all geographic regions, focusing solely on a randomly chosen subset. Similarly, in gauging students' opinions regarding a school's administration, a researcher opts to target specific classes to collect feedback. All students within the chosen classes are given the opportunity to express their perspectives on the school's administrative procedures.[8]

Methodology of Cluster Sampling

Cluster sampling is one of the statistical methods used in research where researchers want to know about a population that is large and spread out.[9]

Steps of cluster sampling

The technique begins with the division of the population into sections called clusters.

(i) Define the population: first you stipulate what population you are interested in, which is often some group that shares one or more features in common, such as where they live.

(ii) Clustering: Then, populations are grouped into clusters that, for example, live in the same geographic area or share same social characteristics, to ensure the sample is a representative of the general population.

(iii) Sampling by clustering: Selection of clusters by an independent random mechanism; the sample size depends on the purpose of research, level of precision needed, and resources available.

(iv) Inclusion of all elements or units in the selected clusters: All elements or units within the selected clusters are counted as part of the sample without the need to randomly select from that cluster.

(v) Data tabulation: This is the stage where the raw data is organized and tabulated.

(vi) Data analysis: This is where the data from the sample that was surveyed are then analyzed using statistical methods, which allow conclusions to be reached about the general population.

Applications of Cluster Sampling

Cluster sampling finds wide-ranging applications across various fields:

(i) Market Research

Cluster sampling, commonly used in market research, is used to assess consumer satisfaction, product preferences, and consumer behavior. Entities such as grocery stores and restaurants can be divided into geographic units (e.g., cities or counties). Researchers can randomly select groups and conduct research. For example, to study consumption patterns in a neighborhood, one can first divide the neighborhood into districts (groups) and simply randomly select the region and then you can conduct a survey or observe a selected group of the members.

(ii) Public Health

Cluster sampling is used in public health research, for example, to study the prevalence of specific diseases in a population, or health-related behaviors e.g., the survey study of the

prevalence of diabetes in a municipality can randomly select regions and survey individuals within the selected regions.

(iii) Social Sciences

Social science studies often makes use of cluster sampling with the aim of analyzing diverse social phenomena, which include schooling, poverty, and crime. For instance, research to examine the effect of educational interventions aimed toward improving scholar performance would possibly use cluster sampling. Researchers ought to randomly choose groups of schools and then ask college students in those randomly selected institutions to take part in the study.

(iv) Environmental Research

When researchers are working to assess ecosystem health and the effects of pollution, cluster sampling techniques can be employed. As an example; the impact of oil spill, can be examined by randomly selecting groups of water bodies, then analyzing the aquatic life in those bodies of water.

I llustrative Scenario Demonstrating Cluster Sampling

Consider a scenario where a company aims to monitor the uptake of a new smartphone in cities across the country. By using cluster sampling, the company chose to group cities and randomly selected a small group for analysis. Individuals in these selected groups are surveyed to gather a comprehensive view of smartphone preferences and usage patterns.

For instance, envision a country with a multitude of cities categorized into distinct clusters:

- Cluster 1: Comprising cities in the North
- Cluster 2: Encompassing cities in the South
- Cluster 3: Covering cities in the East
- Cluster 4: Involving cities in the West

A random sampling procedure is used, so that specific groups such as Cluster 1 (representing cities in the North) and Cluster 3 (including cities in the East) are selected. Thereafter, targeted surveys are conducted on these selected groups to collect data on smartphone preferences, usage patterns and satisfaction levels among local residents.

Survey responses collected from these identified areas (northern and eastern clusters) are optimized using statistical methods. By taking these findings into account, conclusions can be drawn about the overall popularity of the new smartphone in all cities of the country. For example, the high levels of satisfaction and enthusiasm for the new smartphone observed among the surveyed Northeast groups could indicate its high popularity across the country.

Essentially, cluster sampling involves dividing the population into groups, randomly selecting specific groups for analysis, analyzing these selected groups, scrutinizing the collected data, and applying statistical techniques to determine the preference or trends of the population based on the selected groups.

Advantages of Cluster Sampling

(i) When dealing with a widely dispersed population, cluster sampling offers cost savings compared to simple random or systematic random sampling methods.

(ii) It requires less time and effort in contrast to the aforementioned techniques. For example, there is no need for a comprehensive list of all population elements.

(iii) Additionally, instead of individually selecting elements across a vast area, cluster sampling allows for grouping elements within specific geographic regions.[10]

Crucial Issues/Drawbacks of Cluster Sampling

(I) There is a potential for sampling biases and systematic errors. For instance, in the selection of markets, only larger markets might be chosen, albeit randomly, thus potentially impacting the results. Results may differ significantly if smaller markets are excluded from the selection.

(ii) If the clusters chosen are not homogeneous, the final sample may fail to accurately represent the entire population.[10]

Multi-Stage Sampling

Multi-stage sampling, also recognized as multi-stage cluster sampling, constitutes a more intricate variant of cluster sampling, involving the selection of two or more stages within the sample-collection process. Essentially, in multi-stage sampling, substantial population clusters are subdivided into smaller clusters across multiple stages to facilitate a more feasible primary data collection. It is important to note that while multi-stage sampling is not as efficient as simple random sampling, it does mitigate certain drawbacks inherent in simple random sampling, notably its excessive costs and time-consuming nature.[11] Multi-stage sampling involves partitioning the population into separate clusters to minimize the variation between these groups while maximizing the variation within each cluster.[12]

Steps for Implementing Multi-Stage Sampling Technique

(i) Begin by establishing the initial sampling frame by assigning distinct identifiers to each segment within the overall population. Choose a limited sample of distinct clusters to constitute your primary sampling units.

(ii) Develop a secondary sampling frame specifically for the primary sampling units chosen in the preceding step. Subsequently, conduct random sampling procedures within this frame.

(iii) If required, iterate the previous step to further refine the sampling process.

(iv) Ultimately, select the definitive sample group from the subset using a probability-based sampling technique, such as simple random sampling or systematic sampling.[13-15]

Applications of Multi-Stage Sampling

Here are some common applications of Multi-stage sampling

(i) Education Surveys

Multi-stage sampling finds practical use in education surveys where data collection from multiple schools, classes, and students is necessary. For instance, to gauge the effectiveness of a new teaching method, researchers might employ a multi-stage sampling approach by randomly selecting states initially, followed by schools within those states, and eventually specific classes and students within those classes.

(ii) Health Surveys

In health surveys aiming for diverse data across various geographic areas or demographic groups, multi-stage sampling proves beneficial. For example, in studying disease prevalence, researchers might start by randomly selecting regions, then choosing hospitals or health centers within those regions, and finally examining and collecting data from patients within those facilities.

(iii) Market Research

Multi-stage sampling is valuable in market research efforts that require data from different markets or customer segments. For example, a company that wants to analyze customer preferences might start by randomly selecting locations, follow up on stores that sell products in those locations, and finally conduct a survey of customers at those stores.

(iv) Economic Surveys

Multistage sampling proves to be effective in econometric surveys aimed at collecting different types of econometric data from different departments or industries. For example, economists conducting research can randomly select countries or regions, then cities or towns in those regions, and finally households or businesses in those cities and start collecting data on income, expenditure, or operational issues

Illustrative Scenario Demonstrating Multi-Stage Sampling

Consider a research effort aimed at understanding travel habits and preferences by studying traffic patterns in a heterogeneous population, including urban, suburban, and rural areas. To conduct research on people, surveying the population is systematically impossible, prompting multi-stage sampling to obtain representative data.

Implementation of Multi-Stage Sampling

(i) Initial Stage: Regional Selection

Random selection of primary sampling units, such as states or provinces. For instance, randomly choosing five states - A, B, C, D, and E.

(ii) Second Stage: Urban/Town Selection within Identified Regions

Within each chosen state, the random selection of several cities or towns. For example, selecting cities X, Y, and Z within State A, and cities P and Q within State B, continuing similarly across other selected states.

(iii) Third Stage: Identifying Specific Roads/Intersections within Cities/Towns Random selection of specific roads or routes in selected cities or towns. For example, Routes 1, 2, and 3 in City X, and intersections A and B in City Y, continuing similarly in other selected cities.

(iv) Fourth Stage: Commuter Data Collection Monitoring traffic during peak hours or conducting surveys with passengers on selected roads or areas. Data collected should include modes of transportation, departure times, frequency, and travel purposes.

By using multi-stage sampling, researchers effectively capture the diversity of traffic patterns across the country. This approach enables the study of neighborhoods, urban and rural landscapes, and travel behaviors without the need to analyze the entire population, making research practical and cost-effective.

Advantages and Disadvantages of Multi-Stage Sampling

One merit of multi-stage sampling is its ability to efficiently use resources.[16] By targeting specific subgroups within the population, researchers can simplify data collection efforts, reduce costs and exposure time to ensure a representative sample. This focused approach significantly increases the overall efficiency of the sampling process. Furthermore, multistage sampling shows flexibility to complex population structures. Researchers can adjust the sampling method at each stage to fit a hierarchical or stratified population structure, thereby making the final sample more representative.[17]

However, multistage sampling also comes with a number of demerits that researchers should consider. One such demerits is the inherent subjectivity in selection of the clusters in each stage. This theme introduces the possibility of bias, and raises concerns about the integrity and generalizability of research findings.[18] The selection criteria are based on the judgment of the researcher and the availability of information, which may affect quality of the sample. Additionally, there is a risk of sampling error and loss of data. A population segment may be inadvertently excluded, leading to an incomplete representation of the population as a whole and undermining the integrity and reliability of the study results.[19]

Comparison between Cluster Sampling and Multi-Stage Sampling

Aspects	Cluster Sampling	Multi-Stage Sampling
Structure	Population divided into clusters	Hierarchical organization of primary units leading to sub-unit sampling
Sampling Complexity	Simpler compared to multi-stage sampling	It is further complicated by the multiple stages and sampling methods.
Cost-Efficiency	Cost-effective due to cluster selection	It may be more expensive due to the multi-stage process and increased steps
Precision	Less precise due to potential cluster homogeneity	It is more precise with tailored sampling across multiple stages.
Flexibility	Less flexible in terms of sample representation	More adaptable to numerous population structures and characteristics
Resource Optimizatio	Optimal for geographically dispersed populations	Useful for optimizing resources to target specific subgroups

Performing a Comparative Analysis of Cluster Sampling and Multi-Stage Sampling Techniques Using a Free Database

Dataset Description: Open Database of Health Facilities (ODHF)

The dataset used in this study, obtained from the Open Database of Health Facilities (ODHF), includes a wide range of variables to provide a comprehensive overview of healthcare facilities across Canada. It includes important factors for health surveillance and research, e.g.

- Facility Name
- Source Facility Type
- ODHF Facility Type
- Provider Information
- Unit Details
- Street Number and Address
- Postal Code
- City and Province Information
- Source of Street Address
- CSD Name (Census Subdivision Name)
- CSDuid (Census Subdivision Unique Identifier)
- Pruid (Province Unique Identifier)
- Latitude and Longitude Coordinates

Dataset Link: [20]

Available through the Government of Canada's open data repository, this dataset is a sufficient resource for understanding Canadian health data. The multivariate nature of the dataset facilitates detailed analysis, and provides access to healthcare facility type, geographic distribution, and other relevant factors needed for robust analysis in the healthcare industry.

Utilization in this Study

In this research effort, the detailed variability of the ODHF data set forms the backbone of the analysis, enabling detailed insights and informed decisions about sampling strategies. The steps that can be followed for the application of Cluster Sampling and Multi-Stage Sampling methods to this data set are outlined below. Also, recommendation was provided.

Steps for Cluster Sampling

(I) Define Clusters: A researcher could utilize the "Province" variable as the basis for forming clusters.

(ii) Randomly Select Clusters: They could choose a diverse subset of provinces from the dataset using random sampling.

(iii) Include all Units within Selected Clusters: Afterwards, they could incorporate all healthcare facilities within the chosen provinces in the sample.

(iv) Data Collection and Analysis: Finally, they could collect data from selected clusters for analysis, considering the clustered nature of the data in statistical analyses.

Steps for Multi-Stage Sampling

(I) Define Stages: A researcher could identify the hierarchical structure (provinces, cities, healthcare facilities) within the dataset.

(ii) Randomly Select Units at each Stage: Next, they could continue by randomly selecting primary sampling units (PSUs), such as provinces, from the dataset. Subsequently, within each selected PSU, they could randomly choose secondary units (e.g., cities), and further within these cities, randomly select tertiary units (individual healthcare facilities).

(iii) Include all Units at the Final Stage: They have to ensure all healthcare facilities within selected cities are included in the sample.

(iv) Data Collection and Analysis: Finally, they would collect data from selected facilities, treating them as representative subsets, and conduct comprehensive analyses accounting for the multi-stage sampling process.

DISCUSSION

Sampling methods including cluster sampling and multi-stage sampling are important tools in research, facilitating efficient data collection and cross-sectoral analysis. Cluster sampling, in which population is divided into externally similar clusters, offers cost-effective and time-efficient advantages, particularly beneficial for geographically-dispersed populations. Therefore, researchers need to exercise caution. In contrast, multistage sampling, with its hierarchical

approach, addresses some of the shortcomings of cluster sampling by providing an accurate view of population structures This approach proves particularly valuable in datasets with hierarchical characteristics, as revealed by searching the Canadian Open Database of Health Services (ODHF). The recommendation to use multistage sampling in such datasets acknowledges its effectiveness in hierarchical guidance schemes. As researchers evaluate sampling methods and carefully balance the trade-offs between accuracy, robustness, and resource efficiency to suit their specific research objectives, this comparative study serves as a guide valuable, and empowering researchers to make informed choices in choosing appropriate sampling methods for their research.

In summary, both cluster sampling and multistage sampling offer distinct advantages and disadvantages, and the choice of the most appropriate method depends on the unique characteristics of the research situation Understanding the nuances of these methods can inform their analysis found accuracy and reliability have increased.

Recommendation

Considering the provincial distribution of healthcare facilities, and the hierarchical nature of the dataset with details down to individual health facilities, the multi-stage sampling appears to be a more appropriate approach for such dataset. This approach can provide detailed insights into the nature of the healthcare facility. However, successful implementation requires careful planning and resource allocation due to the complexity of the multi-stage process.

AUTHORS CONTRIBUTION

KIO: Idea conception, data collection, article write up,
NF: Help in write-up,
İE: Review writing

REFERENCES

1. Parker K, Nunns M, Xiao Z, Ford T, Ukoumunne O. Characteristics and practices of school-based cluster randomised controlled trials for improving health outcomes in pupils in the United Kingdom: a methodological systematic review. BMC Medical Research Methodology. 2021;21 (1). Available from: https://doi.org/ 10.1186/s12874-021-01348-0

2. Kövi Z, Wongpakaran T, Zábó V, Mirnics Z. Comparison of variable- and person-oriented methodology: examination of Thai and Hungarian psychobiological personality profiles. 2023. Available from: https://doi.org/10.21203/rs.3.rs-2504899/v1

3. Cook D, Rutherford W, Scales D, Adhikari N, Cuthbertson B. Rationale, methodological quality, and reporting of cluster-randomized controlled trials in critical care medicine: a systematic review. Critical Care Medicine. 2021;49(6):977-987. Available from: https://doi.org/10.1097/ccm.0000000000004885

4. Parker K, Eddy S, Nunns M, Xiao Z, Ford T, Eldridge S, et al. Systematic review of the characteristics of school-based feasibility cluster randomized trials of interventions for improving the health of pupils in the UK. Pilot and Feasibility Studies. 2022;8(1). Available from: https://doi.org/10.1186/s40814-022-01098-w

5. Quantilope. Cluster Sampling: Types, Advantages, Limitations, and Examples. Available from: https://www.quantilope.com/resources/cluster-sampling-types-

advantages

6. Voxco. Mastering the Methods of Cluster Sampling. Available from: https://www.voxco.com/blog/cluster-sampling/

7. Taherdoost H. Sampling methods in research methodology; How to choose a sampling technique for research. International Journal of Academic Research in Management (IJARM). 2016;5(2):18–27. Available from: https://doi.org/10.2139/ssrn.3205035

8. Hassan M. Cluster Sampling – Types, Method and Examples. researc-hmethod.net. Available from: https://researchmethod.net/cluster-sampling/

9. Frost J. Cluster sampling: Definition, advantages and examples. Statistics by Jim. Available from: https://statisticsbyjim.com/basics/cluster-sampling/

10. Alvi MH. [Title]. Munich Personal RePEc Archive. [Accessed December 22, 2023]. Available from:https://www.researchgate.net/publication/303941309_A_Manual_for_Selecting_Sampling_Techniques_in_Research

11. Dudovskiy J. Business Research Methodology. [Accessed December 22, 2023]. Available from: https://research-methodology.net/sampling-in-primary-data-collection/multi-stage-sampling/

12. Verial D. Advantages and Disadvantages of Multi-Stage Sampling. Classroom. [Accessed December 22, 2023]. Available from: https://classroom.synonym.com/advantages-disadvantages-multistage-sampling-8544049.html

13. Fernández P, Lovera N, Ramallo L. Sucrose syrup reuse during one- and multi-stage osmotic dehydration of pineapple. Journal of Food Process Engineering. 2020;43(6). Available from: https://doi.org/10.1111/jfpe.13399

14. Adegboyega L. Predisposing factors of recidivism as perceived by prison officers in Kwara state, Nigeria: implications for counselling practice. Mimbar Pendidikan. 2020;5(1):1-14. Available from: https://doi.org/10.17509 /mimbardik.v5i1.24148

15. Okwong O. Internal and external attributions as determinants of athletes- high performance in individual and team sports in selected tertiary institutions, south-west, Nigeria. Advances in Social Sciences Research Journal. 2019.

16. Bi F, Lei M, Wang Y, Huang D. Remote sensing target tracking in UAV aerial video based on saliency enhanced MDNet. IEEE Access. 2019;7:76731-76740. Available from: https://doi.org/10.1109/access.2019.2921315

17. White I, Choodari-Oskooei B, Sydes M, Kahan B, McCabe L, Turkova A, Esmail, H, Gibb,DM, Ford, D. Combining factorial and multi-arm multi-stage platform designs to evaluate multiple interventions efficiently. Clinical Trials. 2022;19(4):432-441.

Available from: https://doi.org/10.1177/17407745221093577

18. Anuradha C, Vijayalakshmi S, Ganesh V, Subramani V. Losses and efficiency calculation for multi-port converter. Available from: https://doi.org/10.1063/5.0108657

19. Dinh P, Fujiwara T, Tho B, Phu S, Giang H. A review of anaerobic digestion systems for biodegradable waste: configurations, operating parameters, and current trends. Environmental Engineering Research. 2019;25(1):1-17. Available from: https://doi.org/10.4491/eer.2018.334

20. Government of Canada. Canada Open Government. 2023. [Accessed December 22, 2023]. Available from: https://open.canada.ca/data/en/dataset/a1bcd4ee-8e57-499b-9c6f-94f6902fdf32/resource/a65aac21-7646-4e92-a619-356628efd669