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Systematic Review on Solid Waste Collection Strategies and their Link to Population and Solid Waste Generation

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Abstract: ***First Class Municipalities, namely Claveria, and Tagoloan and Second-Class Municipalities, namely Balingasag, Jasaan, Lugait, Opol and Villanueva in the Province of Misamis Oriental, Philippines, have different solid waste collection strategies. These seven municipalities have the highest number in terms of population and economic revenue according to the Department of Trade and Industry in 2021. Collecting waste in every household according to schedule in an economical way and correctly segregating waste as much as possible to aim for maximized re-use, recycling and reducing solid waste from every house. This meta-analysis process systematically reviews quantitative literature from various studies and articles to calculate the effects of the different solid waste collection strategies of selected municipalities in Misamis Oriental on their solid waste management program. Simple linear regression analysis was used to identify annual solid waste collection dumped to the municipal-controlled dump site (in cubic meters). The frequency of solid waste collection varies from one municipality to another. Most first-class and second-class municipalities in Misamis Oriental collect solid waste from households two or three times a week. Collection happens door-to-door in less populated communities, while strategic garbage collection areas specified by the barangays occur in densely populated areas. It showed the regression equation y=0.1328x–198.5 and correlation coefficient r-squared value of 0.8616, proving to have a strong and high positive relationship. The study concluded that segregation of biodegradable and non-biodegradable solid wastes is prevalent compared to collection that happens in strategic areas set by the barangay. It was also observed that the 3Rs (reduce, reuse and recycle) endeavors of the municipalities, most of the time, are attained in less populated areas when people prefer to compost biodegradable wastes and segregate recyclable wastes for additional income generation for families and lessen the amount of waste delivered to the dumpsite. It is recommended that the "no segregation, no collection policy" be strictly implemented.***

Keywords: ***Systematic Review, Solid Waste Collection, Solid Waste Strategies, First-Class Municipalities, Second-Class Municipalities, Quantitative Research Design, Simple Linear Regression, Misamis Oriental-Philippines***

I. INTRODUCTION

Solid waste collection strategies in Philippine communities vary from one place to another. The solid waste collection strategies is guided by RA 9003 otherwise known as the "Ecological Solid Waste Management Act of 2000", creating institutional processes, incentives and declaring prohibited acts like dumping of waste matter in public, open burning of solid waste and collection of non-segregated and unsorted wastes just to name a few. Solid waste collection is vital in every city and municipality to maintain quality health and sanitation, improved dignity and quality of life in addition to being compliant to existing laws and regulations of the state. The primary goal of an efficient solid waste collection strategy in municipalities is to eliminate waste materials form households for a healthy community and environment. Waste collection is a crucial phase in solid waste management, activities including wastes placed on bins, collecting wastes from bins and accumulating wastes in the location where the solid wastes collected are emptied in a controlled dumpsite. An increasing urban migration in developed and developing communities is correlated with improved economic activity and living standards [11]. Alongside with urbanization and increased economic activity, living standards of urban dwellers rise, thus households can now afford to purchase goods and the level of consumption is increased. With this condition, the generation of wastes in consequence has now become one of the challenges that cities and municipalities in developing countries is facing [27]. Many issues have not been considered like program awareness and creating monitoring system plus enhancing the process of material recovery facilities by improving segregation and providing recycling facilities that uses scientific programs and capabilities to address the problem [28].

Awareness that poor solid waste management can lead to disease if not being taken seriously by households not doing waste segregation at least [9]. To protect the health and well-being of communities from solid waste related hazards and to improve environmental outcomes, it calls for the development of collection strategies from the local government units and improved domestic waste management in every home.

II. LITERATURE REVIEW

A. *Municipal Solid Waste Management Collection*

Community education and information drive is important in the implementation process of solid waste collection and management. Densely populated barangays in Lugait, Misamis Oriental, a second-class municipality adjacent to Iligan City, has big issues in solid waste collection and management. Mixed collection of solid wastes, illegal incineration of wastes even in dumpsites, emitting polluted air to the communities, delayed or no collection of solid wastes and lack of awareness, acceptance and cooperation form the people are just some of the solid waste collection challenges [5]. Actual status of solid wastes in communities showed huge amount of biodegradable waste from households. Strict implementation of proper segregation should happen to facilitate proper treatment of solid wastes. Information dissemination and education on the compliance of the 3 R's (reduce, reuse and recycle) is important and the policy of "pay as you generate" solid waste will make the community mentally and financially committed to the maintenance of a clean environment [26]. Delayed garbage collection, inconsistent schedule of collection and no strategic garbage collection areas were highlighted as problems of solid waste collection from Claveria, a first class municipality in Misamis Oriental [24]. A study in a state university community solid waste collection found out that garbage collection efficiency is reduced when room-to-room collection is conducted. On the other hand, the use of garbage truck was found efficient in handling waste collection in the campus and community even if collection is done in a once-a-week basis collection frequency. It was found efficient and faster transfer of solid wastes due to minimal garbage truck trips to the disposal area of the municipality [1]. Awareness of the SWM programs of the community, program implementation that should be supported by the community through the efforts of the local government units, waste minimization that includes reduced and wise consumption should be required to achieve the goal of meeting an environmentally sound solid waste management [8]. The simple sorting and segregation strategies of household and domestic wastes can lead to an effective and efficient solid waste management practice in communities. Scheduled collection of solid wastes and incentivising individuals who are effective in the sorting and preparation process of wastes are major factors considered in an effective solid waste management collection strategies in municipalities [3]. Communities are less compliant in SWM policies like waste segregation, composting and recycling. Moderation in the compliance of SWM policies like collection via transport of solid wastes and enforcement of penalties to violators are just few of the suggested measures to enforce SWM policies in the barangay level and the presence of an effective and functioning MRF can be a source of income to the community in addition to composting and recycling of wastes [4]. Thus, the amount of waste collected differs from communities that segregates solid wastes from households compared to neighbourhoods not practicing the segregation.

Solid waste collection strategies in this municipality may be a success in some parts but the biggest problem being faced is knowledge and information about the importance of solid waste management in the barangays, political will and malpractices in waste elimination in households. Mandatory requirement for households to provide compost pit for biodegradable wastes is the prime municipal solid waste program of Balingasag, a second class municipality in Misamis Oriental. Thru the efforts of the Municipal Environment and Natural Resources Office (MENRO) of Balingasag, communities in the municipality had a high level of information and education knowledge about Solid Waste Management. Signage about SWM and the construction and operation of Material Recovery Facility by the local government unit made the communities in the area responsive to SWM programs [13]. The "No-segregation, No-collection Program" made the households to produce only residual wastes to sanitary landfills since composts are mandatory in the municipality. The efforts and perseverance of local government units can make solid waste collection strategies not just compliant to existing laws but a household drive as well, making communities smart in the context of SWM.

B. *Innovative Solid Waste Collection Game Plan*

One of the strategy imposed by the Municipal Environment and Natural Resources Office (MENRO) of Tagoloan, a first class Municipality in Misamis Oriental and adjacent from the eastern part of Cagayan de Oro, is to schedule three (3) times a week the collection of Biodegradable solid wastes from various barangays and strategic garbage collection areas and four times a week the collection of Non-Biodegradable/Residual wastes around the municipality [14].

With this type of collection strategy, households and business operators are forced to segregate their wastes or else they will be the one to suffer for no collection of non-segregated wastes. The efforts of Villanueva, a second class municipality in Misamis Oriental to decrease the volume of solid waste being dumped to the municipal controlled dump site created the program of Barangay Poblacion exchanging of grocery goods to recyclable and reusable solid waste. A very promising program by the Municipal Environment and Natural Resources Office (MENRO) of Villanueva is, exchanged recyclable and reusable solid wastes from the public are sold to partner junkshop and proceeds will go to the "Basura Store", buying basic commodities that people will receive in exchange to the said wastes incentivises waste recycling and re-use in the community [15]. Meanwhile, residual wastes from households will be collected regularly and will reach the Residual Containment Area in the municipality. It was also observed that the program is receiving positive community acceptance and is doing well after one year from its implementation. Innovations in solid waste management specially in urban areas should highlight information drive and awareness in the entire population to obtain best results and acceptance of new technologies on the way [6]. An integrated system through household practice of refuse solid waste disposal in rural areas and dumping biodegradable wastes in open backyards to be used in gardens and lawns is a common practice that decreases solid waste going to controlled dumpsites [12].

C. Effects of Poor Solid Waste Collection Strategies on the Environment

Economic, social, environmental and public health factors are directly affected by waste management. Population growth and municipal waste should have holistic approaches, such as the reuse of solid waste to produce energy for the services that need electricity [17]. The extent of marine environment pollution caused by poor collection strategies of solid waste was investigated in Opol, a second class municipality, having its northern territory bounded by the Macajalar Bay and adjacent to Cagayan de Oro City from its western side and Jasaan, a second class municipality in Misamis Oriental and possesses the Macajalar Bay on its northern boundary. Poor education and information drive, according to interviewed people, caused them to pollute the beaches and seas in addition to wastewaters from the industries. In the existence of dense population in these municipalities, the lack of garbage disposal areas like MRFs and sanitary landfills polluted the body of water, which is a source of revenue as centers of tourism activities in the said municipalities [30]. The efficiency of municipal solid waste management in municipalities, which includes collection strategies of waste, influences the waste management practices of the community. In municipalities where full implementation of solid waste management is low, the people in the community resort to burning waste and open dumping as alternative means of disposing of solid waste. It is also indicated that community engagement in solid waste management is poor, as residents feel the responsibility of an efficient municipal solid waste management lies in the hands of the local government unit alone [16].

D. Collection and Transport of Solid Wastes provided by RA 9003

The role of the local government units is primarily the responsible implementation and enforcement of RA 9003 in its political territory and respective jurisdictions. Waste segregation and collection shall be at the barangay level focusing on biodegradable and compostable wastes and the collection of non-recyclable wastes shall be the responsibility of the city or municipality (Art. 2 Sec. 10, RA 9003) [22]. Minimum requirements and standards for the collection of solid wastes in the Philippines is provided with a law in 2001, where; (a) the safety and well-being of the persons involved in the collection of solid wastes shall be in complete protective gears and equipment for protection from hazards in handling solid wastes, (b) education thru needed trainings in handling solid wastes in accordance to the law shall be provided to the personnel and collectors to ensure the proper handling of the solid wastes and (c) during the collection of solid wastes, damage to containers, spillage of solid wastes in the collection area shall be prevented (Art. 3 Sec. 23 a-c, RA 9003) [22].

It is also required that transport of solid wastes shall be separated on schedule and trucks/haulers for specific types of wastes, otherwise, collection trucks shall have compartments to ensure efficient separation of solid wastes while in transit to controlled dump sites and MRFs. Transport vehicle design shall consider the road/road size of the community and capacity to make sure that safe and efficient collection plus transport of solid wastes is considered. The focus between urban forms and transport-related carbon dioxide emissions [31] and from transporting domestic wastes adds up to pollution. Transport compartments shall be covered to ensure the utmost containment of wastes during travel. Lastly, for purposes of identification, garbage trucks shall visibly bear complete body number, contact number of the operator, the LGU and the agency collecting the solid wastes (Art. 3 Sec. 24, RA 9003) [22].

Some prohibited acts in RA 9003 involving collection and segregation strategies are as follows; throwing, and dumping of solid wastes in public places likes road and sidewalks including interior bodies of water like esteros and canals, the open burning of solid wastes, permitting collection of non-segregated wastes, dumping of wastes in flood prone areas,

mixing in one waste bin recyclable and non-recyclable wastes, removal of recyclable materials intended for collection by authorized personnel and use of non-acceptable packaging material like one time use plastic bags (Ch. VI Sec. 48, RA 9003) [22]. This highlights the importance of solid waste collection strategies to the waste management program of the local government unit.

III. METHODOLOGY

The research methodology of this study is guided with systematic review process in the context of solid waste collection strategies in the first-class and second-class municipalities of the province of Misamis Oriental in the Philippines and various solid waste collection techniques being utilized in communities within these municipalities to lessen the wastes being transported to existing common dump site and Material Recovery Facilities in selected communities.

Published journal articles, conference papers, legitimate social media pages from local government units and other related publications were used to progress the study based on the elements of data source authenticity, data accuracy and consistency and legitimate character of the authors. The primary intent of this study is to develop a comparison and analysis from existing available literature [23]. Using quantitative analysis as a method for analysing numerical data collected via online articles and considering pre-existing statistical figures will help in the computational analysis of the study. The computationally analysed findings in a heterogeneous group will explain a particular phenomenon in the study of solid waste management [2].

An accurate meta-analysis to interpret clear results in ways accessible to a wide variety of audiences reflects the multivariate and multi-level nature of effective study from limited data is considered a minimal requirement for a high-quality meta-analysis [21]. Literature from the latest years can help in the credibility of the study when updated data values are used in the discussions, including a high number of articles published recently can create reliable mathematical solutions. Simple linear regression analysis was used to identify annual solid waste collection dumped at the municipal controlled dump sites (in cubic meters), effective collection strategies dominant factors [25]. The simple linear regression between the population of first-class and second-class municipalities to the annual solid waste collection dumped to the municipal-controlled dump sites (in cubic meters) is used to determine the correlation of the collected data. The regression formula Y= a + bX will also be used to determine the R-squared.

A. The Research Setting

Misamis Oriental is a province in the Philippines situated in the Northern Mindanao of Region 10, known as the “Gateway Province to Mindanao”. According to the Philippine Statistics Authority, the province has a land area of 3,131.52 square kilometers or 1,209.09 square miles. Its population, as determined by the 2020 Census, was 956,900. This represented 19.05% of the total population of the Northern Mindanao region, 3.64% of the overall population of the Mindanao island group, or 0.88% of the entire population of the Philippines. Based on these figures, the population density is computed at 306 inhabitants per square kilometer or 791 inhabitants per square mile [19]. First class municipalities of the province are Claveria and Tagoloan and the second class municipalities of the province are Balingasag, Jasaan, Lugait, Opol and Villanueva where chosen in this study since these municipalities share a bigger portion of the pie to the amount of gross solid wastes dumped into municipal controlled dumpsites according to the DENR 2021 – Climate Change GHG Inventory and the highest number of population in the province of Misamis Oriental according to the CENSUS of 2020 [20][29].

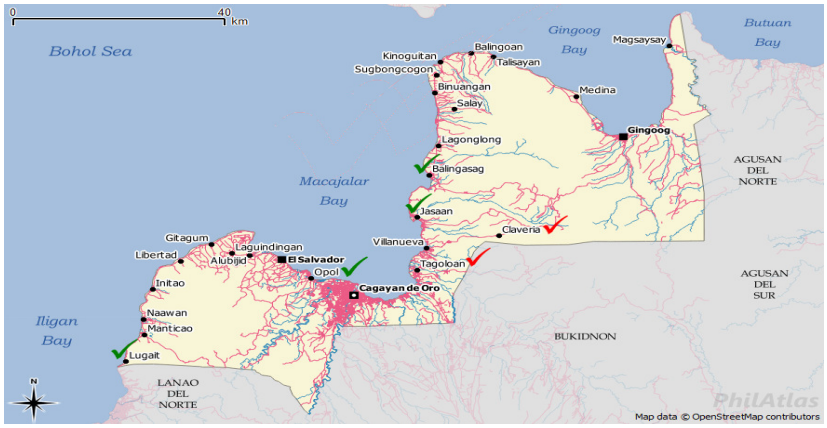

Figure 1. Map of the Province of Misamis Oriental showing the first-class and second-class municipalities of the province.

Figure 1 shows the map of Misamis Oriental, First-class municipalities of the province are Claveria and Tagoloan directed by a red check mark and the second-class municipalities of the province are Balingasag, Jasaan, Lugait, Opol and Villanueva directed by a green check mark on the map.

IV. RESULTS AND DISCUSSIONS

The systematic review of published scientific articles from independent studies focused on the solid waste collection strategies and their effectiveness and correlation to the amount of solid waste dumped at controlled dump sites in first class and second-class municipalities in the Province of Misamis Oriental, Philippines.

Table 1. Solid Waste Collection Strategies and articles used in the Systematic Review.

Solid Waste Collection Strategies	Articles used in the Meta-analysis
1. Scheduled collection of solid waste in communities	Camarillo & Bellotindos, 2021 Breva, 2020 Arazo & Ido, 2016
2. Strategic location of garbage	Arazo & Ido, 2016
3. Mandatory compost pit per household (backyard compost)	MENRO Balingasag Khalil & El-Sherif, 2022 Camarillo & Bellotindos, 2021 Breva, 2020
4. “Basura Store Policy”	MENRO Villanueva Breva, 2020 Matunog & Awa, 2015
5. Strict Compliance of the “no segregation, no collection policy”	MENRO Tagoloan Breva, 2020 Matunog & Awa, 2015
6. Scheduled collection of segregated biodegradable and non-biodegradable wastes	MENRO Tagoloan Breva, 2020 Camarillo & Bellotindos, 2021 Fadhullah et al., 2022
7. Require household to practice 3R’s (reduce, reuse and recycle)	Breva, 2020 Macusi *et.al*, 2019 Matunog & Awa, 2015
8. Information dissemination and education drive of solid waste management to communities	MENRO Balingasag Camarillo & Bellotindos, 2021 da Roza *et. al*, 2020 Macusi *et.al*, 2019 Matunog & Awa, 2015
9. “Pay as you generate policy”	Camarillo & Bellotindos, 2021 Matunog & Awa, 2015

Table 1 shows the list of solid waste collection strategies and the respective published scientific articles from independent studies used in the meta-analysis were listed to show the relevance of the collection strategies to the amount of solid waste dumped at controlled dumpsites in first-class and second-class municipalities in the Province of Misamis Oriental, Philippines.

Table 2. Misamis Oriental first-class and second-class municipalities, population, annual solid waste collection and collection strategies and techniques

Misamis Oriental Municipalities	Class	Population/ Source: Census 2020	Annual Solid Waste Collection dumped to Municipal Controlled Dump Site (in cu.m average) Source: DENR 2021 – Climate Change GHG Inventory	Solid Waste Per Capita Generation Rate (kg/day) Source: DENR 2021 – Climate Change GHG Inventory	Collection Strategies and Techniques
Lugait	2nd Class	20,559	1,948.96	0.25 kg/day	x *a) rampant illegal incineration* x *b) no segregation of solid wastes*
Villanueva	2nd Class	40,419	5,593.41	0.36 kg/day	✓*a) "Basura Store" is practiced*
Claveria	1st Class	52,478	5,789.00	0.30 kg/day	✓*a) scheduled collection of solid wastes in communities* ✓*b) strategic location of garbage collection areas*
Jasaan	2nd Class	57,055	8,330.03	0.07 kg/day	x *a) lack garbage collection areas* x *b) inconsistent solid waste collection schedule*
Opol	2nd Class	66,327	10, 192.15	0.42 kg/day	x *a) lack garbage collection areas* x *b) inconsistent solid waste collection schedule*
Balingasag	2nd Class	74,385	9,789.92	0.37 kg/day	✓*a) mandatory compost pit per household* ✓*b) strict compliance for the "no segregation, no collection"* ✓*c) information dissemination and education drive of SWM*
Tagoloan	1st Class	80,319	8,947.39	0.31 kg/day	✓*a) scheduled collection for biodegradable and non-biodegradable wastes* ✓*b) strict compliance for the "no segregation, no collection"* ✓*c) "pay as you generate" policy*

Table 2 shows Lugait, a second class municipality with a population of 20,559 in the Census of 2020 has an average annual solid waste collection of 1,948.96 cu.m dumped to the controlled dump site and 0.25 kg/day Solid Waste Per Capita Generation Rate. In most communities in this municipality rampant illegal incineration of solid wastes is recorded and no segregation of wastes is being practiced. Villanueva, a second class municipality with a population of 40,419 in the Census of 2020 has an average annual solid waste collection of 5,593.41 cu.m dumped to the controlled dump site and 0.36 kg/day Solid Waste Per Capita Generation Rate. This municipality has a good solid waste management practice in the form of "Basura Store" where recyclable wastes are exchanged with goods like rice, canned goods and other products needed by households. Claveria, a first class municipality with a population of 52,478 in the Census of 2020 has an average annual solid waste collection of 5,789.00 cu.m dumped to the controlled dump site and 0.30 kg/day Solid Waste Per Capita Generation Rate.

It has consistent solid waste collection schedule in most communities. Jasaan, a second class municipality with a population of 57,055 in the Census of 2020 has an average annual solid waste collection of 8,330.03 cu.m dumped to the controlled dump site and 0.07 kg/day Solid Waste Per Capita Generation Rate. In this municipality, inconsistent solid waste collection schedule happens and most areas lack garbage collection areas. Opol, a second class municipality with a population of 66,327 in the Census of 2020 has an average annual solid waste collection of 10,192.15 cu.m dumped to the controlled dump site and 0.40 kg/day Solid Waste Per Capita Generation Rate. It also lacks garbage collection areas in most communities and is inconsistent solid waste collection schedule. Balingasag, a second class municipality with a population of 74,385 in the Census of 2020 has an average annual solid waste collection of 9,789.92 cu.m dumped to the controlled dump site and 0.37 kg/day Solid Waste Per Capita Generation Rate. This municipality has imposes mandatory compost pit per household and has strict compliance to the "no segregation, no collection policy" in its community. Tagoloan, a first class municipality with a population of 80,319 in the Census of 2020 has an average annual solid waste collection of 8,947.39 cu.m dumped to the controlled dump site and 0.31 kg/day Solid Waste Per Capita Generation Rate. It has a good program for solid waste collection and follows scheduling of solid waste collection for biodegradable and non-biodegradable wastes and has strict drive for the "no segregation, no collection" in the municipality.

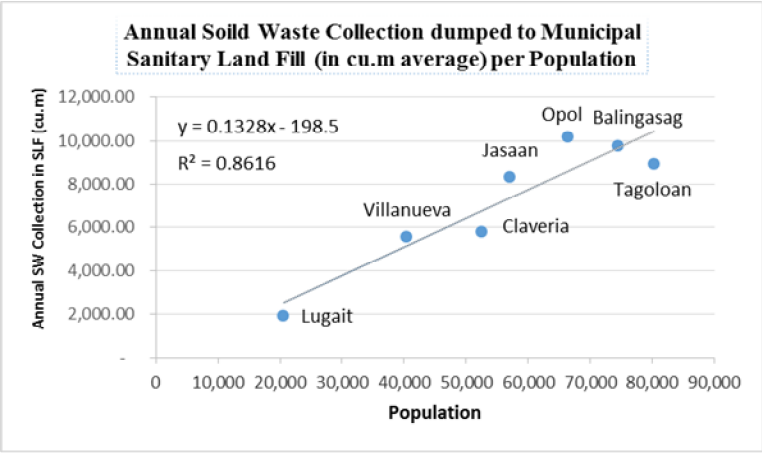

Figure 2. Annual Solid Waste Collection dumped to Municipal Controlled Dumpsite (in cu.m average) per Population.

Figure 2 shows the Simple Linear Regression's positive correlation between the population of first class and second class municipalities (y) to the annual solid waste collection dumped to the municipal controlled dump site (in cubic meter) (x). It also shows the regression equation y=0.1328x – 198.5 and correlation coefficient r-squared value of 0.8616.

V. CONCLUSION

The amount of annual solid waste collection dumped into municipal controlled dumpsite (in cubic meter) in first-class and second-class municipalities in Misamis Oriental, Philippines, is directly proportional to the population size of the community. In this study, it was observed that when municipalities practice effective solid waste collection strategies and innovations like, strong information and education drive about solid waste management, scheduled collection of solid wastes in communities, strict compliance for the "no segregation, no collection policy", scheduled collection of biodegradable and non-biodegradable wastes, mandatory compost pit per household and the "Basura Store", where recyclable wastes are exchanged with goods like rice, canned goods and other products needed by households the amount of annual solid waste collection volume dumped to the municipal sanitary land fill is decreased respectively. This observation is proven to have a strong and high positive relationship, having the correlation coefficient r-squared value of $-1 < 0.8616 < 1$. A correlation coefficient r-squared value of 0.8616 means that the predictors explain 86% of the variation in the response variable.

This study suggests that the local government units and other authorities to design and implement religiously the solid waste management and collection strategies in the communities of the municipalities like waste separation and segregation programs, incentivising the households conducting the 3 R's (reduce, reuse and recycle), compost pit approaches to biodegradable wastes, information and education drive to communities and strategies to ensure high participation rate to solid waste management programs. This study also suggests focusing on community and hands-on involvement in waste separation and segregation and recycling as a form of good habit and a way of life in the family.

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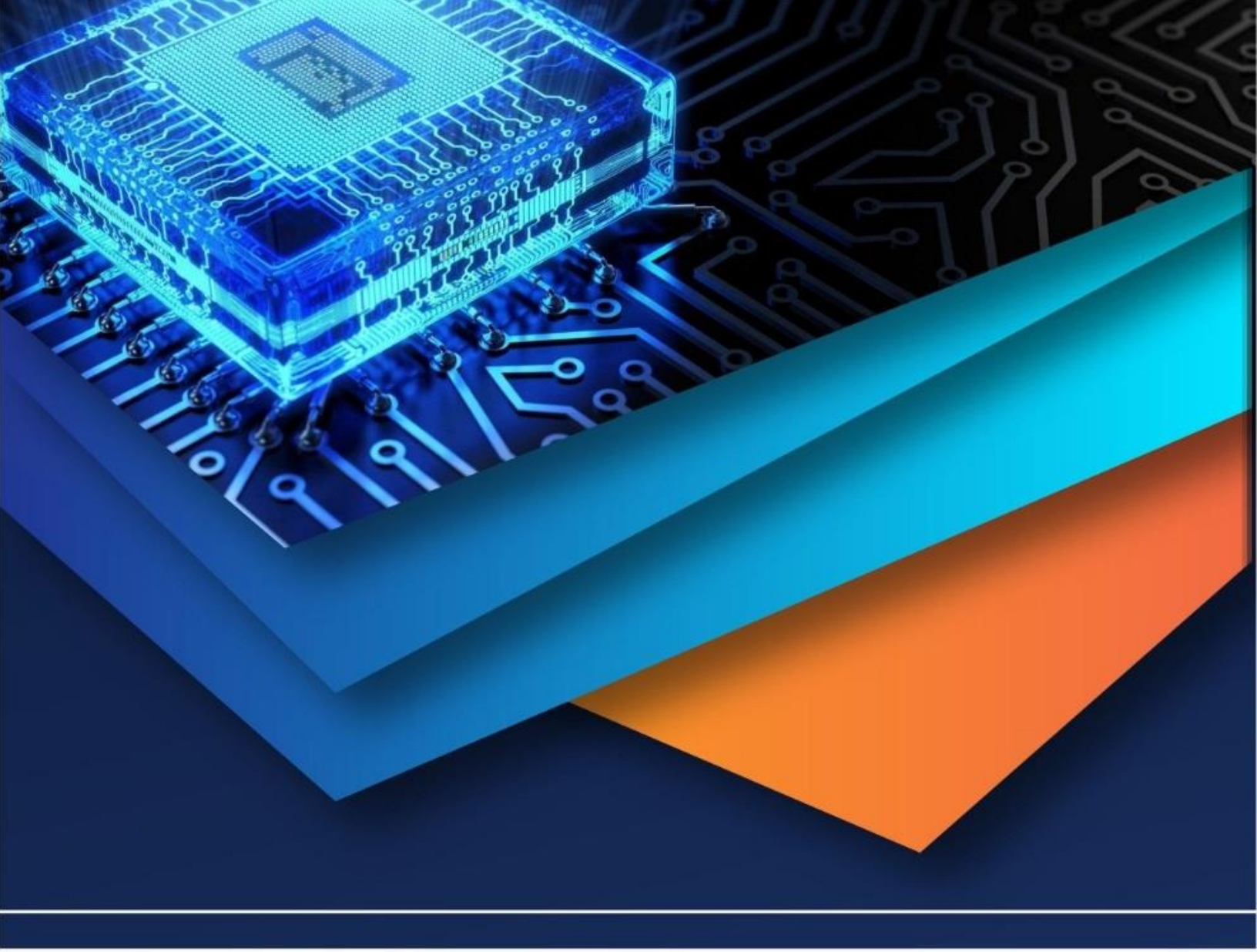

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