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Physical Characterization of Urban Solid Waste and the Economic Potential of Recoverable Materials at "Loma de los Cocos" Landfill in Turbaco - Colombia

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Abstract: This work was done with the purpose of having specific information that allowed to know the characteristics and amount of Solid Residues (RS) that are generated in the municipality of Turbaco in Colombia and that are disposed in the landfill of the "Environmental Park Loma de los Cocos ".

Among the results obtained was the generation of 63.5 Ton / day of RS (0.53 kg/hab/day). The percentage of organic matter or biomass corresponded to 58.34% and 27.22% to recoverable materials that are not currently separated before entering the landfill process. The results indicated that it is feasible to use plastics, paper and paperboard, aluminum, glass and ferrous and non-ferrous materials. To this end, it is suggested to implement a separation system at the source and a material recovery and transformation plant. This management system would divert up to 27.22% of the RS generated to economic potential equivalent to $ 229,969,452 per year, which would imply an opportunity for the creation of microenterprises to generate formal employment and a significant extension of the life of the landfill. On the other hand it would contribute to the reduction of the pollutant emissions generated by the landfill and would facilitate the better homogenization of the compost of the organic residues for the regeneration and conservation of cultivated soils in the region.

In addition, Resolution 0754 of 2014, which adopts the methodology for the formulation, implementation, evaluation, monitoring, control and updating of the Comprehensive Solid Residues Management Plans (PGIRS) in Colombia, would be implemened.

Keywords: Solid Residues, PGIRS, recycling, landfill, waste.

I. INTRODUCTION

Undoubtedly, to orient the exposition of the subject, it is necessary to address the generalized concept associated with Solid Residues (RS) in its broad conception. Like many environmental issues, the evolution of SR conceptualization at the academic, scientific and social levels has changed over time. An initial definition states that "solid residues is defined as waste that is transported by water and has been rejected because it will no longer be used" [1]. Without a doubt, this conception is nowadays quite complicated in the light of recognizing that "the term residue does not correspond to the meaning of the word waste, since it implies the non-utility of matter" [2]. The discussion on the subject has been very broad and the reality shows that until the 1970s, RS were known indiscriminately as "garbage" and it was only until the mid-1980s that technical arguments were made that allowed understand that "the designation of residue is much more appropriate than that of waste, refuse or waste" [3].

It has not been easy, but with the passage of time the imaginary of the community collective has been assimilating the difference between the concepts trash and solid residues, to the point that the RS are understood as the materials resulting from a process, usually industrial or domiciliary that are susceptible to reincorporate to take advantage of the general eco-systemic production cycle. On the contrary, waste is conceived as the last waste that does not have the quality of being recovered, reused or recycled and whose only option is the technical treatment to mitigate its negative environmental impact when they are ready. In other words, it can be said that garbage should be cataloged in a unified way for the whole world, in the very near future, as the subsequent residue of all activity, that is, as waste from RS. [4]

In this sense, the importance of the SR concept has been so important that today, the countries and their cities have rules aimed at promoting in a positive and organized way, the logistics chain of RS to their disposal site. In the case of Colombia, the national

government through the Ministry of Environment, Housing and Territorial Development since 1998 established the policy for integral residues management which is oriented to promote processes of minimization, exploitation, recovery, treatment and disposal controlled of the residues, articulating the integral management of the solid residues with the provision of the public toilet service. For its part, Decree 1713 of 2002, included the Comprehensive Solid Residue Management Plan (called PGIRS by its acronym in Spanish) as an essential planning method for the proper use and use of RS.
The PGIRS has as one of its main components the quantification and standardization of RSs produced by a particular sector (institutional, residential, industrial, etc.), to determine the potential of exploitation according to its properties and conditions of the market. The characterization is carried out by means of a gauge, which allows to determine the percentage of organic matter, paper, glass, residue electrical and electronic equipment (WEEE), among other kinds of waste that are generated in a certain place. In the same way it allows to evaluate the physicochemical and biological composition of the residue, which will be the basis for the decision making on its use, treatment and final disposal.

II. THEORETICAL FRAMEWORK

A. Management
Is the set of activities that are carried out from generation to disposal of solid residue or disposal. It includes the activities of separation at source, presentation, collection, transportation, storage, treatment and / or disposal of solid residues or residues.

B. Characterization
Determination of the qualitative and quantitative characteristics of solid residues, identifying their contents and properties.

C. Daily Production Per Capita
Amount of solid residues generated by a person, expressed in terms of kg /hab/day or equivalent units, according to the gauges and the number of persons per household estimated by the Dane[2].

D. Separation at the Source
Is the classification of solid residues at the site where they are generated for later recovery.

E. Presentation
Is the activity carried out by a user in order to package, pack and identify all types of solid residues for storage and subsequent delivery to the entity providing the toilet for harvesting, transportation, treatment and final disposal.

F. Storage
User action to temporarily place solid residues in containers, returnable or disposable containers while processed for use, processing, marketing or presented to the collection service for treatment or final disposal.

G. Exploitation
In accordance with the framework of the Integrated Management of Solid Residues (GIRS), is the process of integrated management of solid waste, in which, recovered materials are reincorporated into the economic and productive cycle efficiently, through reuse, recycling, incineration for energy generation purposes, composting or any other modality that entails health, environmental, social and / or economic benefits.

H. Recovery
It is the action that allows to select and to remove the solid residue that can undergo a new process of use, to turn them into useful raw material in the manufacture of new products.

I. Recycling
It is the process by which the recovered solid residue is used and transformed and the potential of reincorporation as raw material for the manufacture of new products is returned to the materials. Recycling can consist of several stages: clean technology processes, industrial reconversion, separation, selective collection, reuse, transformation and commercialization.

J. Reuse

Is the extension and adequacy of the useful life of recovered solid residue. It is based on the fact that processes, operations or techniques return to the materials their possibility of use in their original function or in a related function, without requiring additional transformation processes.

K. Solid Residue that can be used

It is any material, object, substance or solid element that has no direct or indirect use value for who generates it, but which is susceptible of incorporation into a productive process.

L. Non-Usable Solid Residue

Any solid or semi-solid material or substance of organic and inorganic origin, putrescible or not, from domestic, industrial, commercial, institutional, service activities, which does not offer any possibility of use, reuse or reincorporation in a productive process. They are solid residues that have no commercial value, require treatment and final disposal and therefore generate disposal costs.

M. Collection

Is the action and effect of collecting and removing solid residue from one or more generators carried out by the person providing the service.

N. Treatment

Is the set of operations, processes or techniques by which the characteristics of solid residue are modified, increasing their possibilities of reuse or to minimize environmental impacts and risks to human health.

O. Elimination

Any operations that can lead to final disposal or recovery of resources, recycling, regeneration, composting, direct reuse and other uses.

P. Final Disposal of Solid Resiudes

It is the process of isolating and confining solid residues, especially those not used, in a definitive way, in specially selected places and designed to avoid contamination, and damages or risks to human health and the environment.

Q. Storage unit

Is the defined and closed area, in which are located the storage boxes in which the user temporarily stores the solid residues.

R. Hazardous Residues

Are those produced with any of the following particular characteristics: infectious, combustible, flammable, explosive, reactive, radioactive, volatile, corrosive or toxic that may cause harm to human health and the environment. Containers and packaging that have been in contact with them are considered dangerous.

S. Non-Hazardous Residues

Those produced in any place and in the development of an activity that presents no risk to human health or the environment. This group includes biodegradable, recyclable, inert and ordinary or common residues.

T. Organic Residues

They are all those that can decompose naturally and that have in their structure basically Carbon, Nitrogen, Oxygen, Hydrogen. These can be: paper, vegetable peels, food residues, fruits, beverages, crop residues, algae, tree leaves, etc.

U. Inorganic Residues

Are those that by their chemical characteristics undergo a very slow natural decomposition. Many of them are of natural origin but are not biodegradable as they are plastic containers, cans, glasses, batteries, among others. They are usually recycled through artificial and mechanical methods.

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III. BACKGROUND

In the Colombian territory, some municipalities present all kinds of problems with regard to public services, such as water shortages due to lack of a drinking water treatment plant, lack of sewerage, inadequate final disposal of solid waste, among others. [5]

Regarding the municipality of Turbaco, the study population of the present study located on the Colombian Caribbean coast, it must be said that some time ago the scenario of residues collection had a coverage not exceeding 35% in the urban area and it was only until 2012 , when it began to have a complete collection service whose immediate objective was the proper management of the same, with final disposal site in the landfill located in the surrounding municipality of Turbana to 10.4 kilometers of Turbaco within the "Parque Ambiental Loma de the Cocos ", coordinates 10º 16'21" north and 75º 29'10 "East. With access through the route Mamonal - El Bosque or the Mamonal Way - Gambote. It should be noted that the lot where the RS of the municipality is available and operates the regional dump, has a total area of 63.87 Hab and in its geographic area are available land not suitable for activities of bioconversion of organic material, treatment and final disposal of resiudes hospital, hazardous and special residues.

Thus, based on the novel conditions mentioned above, it was found that for the municipality of Turbaco, the available and reliable baseline records related to the generation, collection and disposal of solid residues are insufficient. Table 1 shows respectively the information currently available and related to the management of RS for Turbaco.

Parameter / Year	2012	2013	2014	2015	2016
RS Collected (Ton/year)	15.228	18.312	20.465	21.066	22.854
RS Collected (Ton/month)	1.269	1.526	1705,4	1.755,5	1.904,5
RS Collected (Kg/day)	41.720	50.170	56.069	57.715	63.483,2
Dane[2] 2005 Habitants projection (urban)	98.921	101.789	105.161	109.034	119.178
Producción per cápita (Kg/hab/day)	0,42	0,49	0,53	0,53	0,53

Table 1: Solid residues generation (RS) per year - Turbaco. 2016

IV. METHODOLOGY

As a source of primary information, the field data obtained in the implementation of the association agreement SECGEN No 0000007 of May 27, 2016, established between the Technological Foundation Antonio de Arévalo -TECNAR and the municipality of Turbaco, whose main purpose was the Update of the Integrated Management Plan for Solid Waste (PGIRS) of the territorial entity.This was done to comply with the provisions of decree 1077 of 2015 and resolution 754 of 2014 of the national government of Colombia.

Map 1: Location Loma de Los Cocos landfill – Turbana (Col). 2017

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In that order of ideas and with the intention of having specific information that would allow us to know the type and quantity of RS collected at the Loma Environmental Park of Los Cocos in the municipality of Turbaco as well as the characterization and quantification of them, proceeded to to carry out a series of activities with a methodological basis that allowed to reach the object of this study. They are described below.

A. Methodology of the Characterization

The procedure performed took into account the classification scheme according to the provenance of solid waste (residential, industrial, institutional, hospital or sweep), the samples characterized in the landfill were residential type. According to the classification scheme taking into account the feasibility of handling and disposal (common or special), common type samples were taken. Finally according to the classification of the type of dangerousness (common or dangerous), it is reported that the samples characterized were of common type. The quantification and characterization of the solid wastes was done using the Standard: ASTM D 5231 - 92 "Standard Test of the Composition of Unprocessed Municipal Solid Wastes", method technically recommended by international standards. The standard includes procedures for collecting samples representative of RS, manual separation of individual components, data collection and reporting of results. Random sampling was carried out directly in a special area of the landfill, since in the municipality there are no recycling programs at the source. Samples were taken between 800 and 1200 kg directly from the collection trucks that provide the collection service to the municipality.

B. Definition of the Characterized Routes

The operational plan for the 13 collection routes of Bioger S.A. - E.S.P. established for the municipality, was used as base information for the generation of the work plan for the characterization of RS in the municipality. For four (4) weeks, two (2) consecutive days were chosen for collection of samples: Monday and Tuesday, Wednesday and Thursday, Friday and Saturday, and Sunday and Monday.

C. Delimitation of the Characterization Area

We proceeded to delimit and organize a special area of the landfill for the direct unloading of the collection trucks in order to proceed with the sampling of the RS.

Figure 1: Delimitation of landfill area for collection of samples. 2016

D. Download from the Collectors

In the discharge area defined for the sampling process, each truck left a representative part of the dragged content. Three (3) and four (4) samples were worked per day.

Figure 2: Unload truck collectors. Landfill. 2016.

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E. Identification, Handling and Preparation of Samples

Using ropes fixed to the floor, lines were drawn on previously homogenized samples, trying to represent a Cartesian plane (x, y). Once the sample was divided, two (2) opposing parts per vertex were discarded and the remainder were homogenized again by paddling. The same procedure was performed until the third quartet was completed. After the quartets in stages, final samples were weighed between 80 and 125 kg.

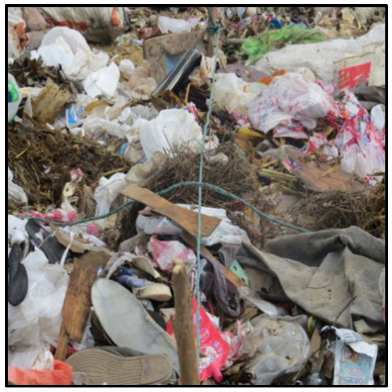

Figure 3: Preparation of samples. Landfill. 2016

F. Sample Selection and Weighing

Once the definitive samples of the quartet process had been taken, they were collected and weighed. The data obtained were recorded in the monitoring template.

Figure 4: Collection and weighing of final samples. Landfill. 2016

The determination of the physical composition was made based on the total weight of the sample selected and by means of the following equation the percentages of each category were obtained.

$$P_i = \frac{PM_i}{PT} * 100$$

Where:

P_i = Percentage by weight of material (%)

PM_i = Weight of material i (kg)

PT = Total weight of the sample (kg)

G. Results of the Samples

After determining the percentage by weight of each of the by-products already classified, it was found that of the 27 samples taken by adding the weighted percentages by categories, the total was always above 95%. If in any case the value had been lower, the rule recommends the repetition of the process which would have been done. The final result of the characterization of the samples is shown below.

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Physical Composition Form					
Date		September of 2016			
No Sample	Average	Time		Day	
Path	Turbaco	Plate			
Total Weight Sample		2.208,70			

Component		Weight (Kg)	Average Weigth (Kg)
Organics.		1.288,53	58,34%
Paper.		101,23	4,58%
Paperboard.		124,29	5,63%
Plastic	High density	97,25	4,40%
	Low density	174,11	7,88%
Rubber and Leather.		43,16	1,95%
Textiles.		55,89	2,53%
Woods		19,98	0,90%
Metals	Copper	0,00	0,00%
	Iron	35,61	1,61%
	Aluminum	1,48	0,07%
	Bronze	0,00	0,00%
	Nickel	0,00	0,00%
	Lead	0,00	0,00%
Glass		67,40	3,05%
Ceramic products, ashes, rocks and debris.		44,15	2,00%
Bones		24,95	1,13%
Hygienic		109,34	4,95%
Icopor		21,33	0,97%
Electrical		0,00	0,00%
TOTAL		2.208,70	100,0%

Table 2: Final weighted physical composition of RS collected – Turbaco (Col). 2016

H. Economic Potential of Sub-Products in the Municipality of Turbaco, Bolívar

According to national single decree 2981 of 2013, which regulates the provision of the public toilet service in Colombia, the use has been defined as "the complementary activity of the public toilet service that includes the collection of separable waste in the source by the users, selective transport to the sorting and harvesting station or to the harvesting plant, as well as their sorting and weighing."

In order to determine the economic potential of the usable RS, the profitability calculation was carried out, which took into account the operating and marketing expenses of the same.

1) *Calculation of RS that can be used:* After the physical characterization was carried out, the amount of RS that could be used was calculated based on the total production of the same ones shown in table 1 which, as observed for 2016, corresponded to a value of 1,905.4 tons / month. It also took into account the population of the municipality that is 116,880 people according to the projection Dane 2005 and the production of RS per capita calculated that was 0.53 kg / hab / day. In any case, the fact that only 70% of inorganic RSs such as paper and paperboard can be used, while others such as aluminum and iron can be recovered in 100%, as well as plastics, PET, multilayer packaging and glass.

Table 3 shows the projection of the RS to be reused through commercialization, where the produced are those generated by the population and the recovered ones refer to those that are produced in quality conditions to be actually marketed.

Tipo RS	%	Potencial Offer(Ton/month)	
		Produced	Recovered
Paper	4,58	23,74	16,62
File	2,00		
Magazine	1,53		
Newpaper	1,05		
Phone Guides	0,00		
Cleans	0,00		
PaperBoard	5,63	29,18	20,46
Kraft	1,88		
Corrugated	2,00		
Youthful	1,75		
Glass	3,05	15,81	15,81
Transparente	3,05		
Ambar	0,00		
Green	0,00		
Plastics	12,28	63,66	63,66
PET	4,00		
PEAD	2,00		
PVC	0,50		
PEBD	2,30		
PP	2,50		
PS	0,98		
Others	0,00		
Non Ferrous Scrap	0,07	0.36	0.36
Aluminum	0,07		
Non Ferrous Scrap	1.61	8,34	8,34
Total	27,22	141,09	125,25

Table 3: Offer of Solid Waste – Turbaco (Col.). 2016

2) *Costs Generated by Commercialization of Usable RS:* As expected the marketing activity of the usable RS, implies a projection of logistical expenses in which it is necessary to incur in order to be executed. The summary of the result of the annual / monthly expense exercise for the operation is shown below in table 4.

Activities	Annual Cost ($)	Mensual Cost ($)
Operation and maintenance (Elements of personal protection, rent, utilities, locative adjustments, machinery and equipment maintenance, administrative expenses, etc.)	75`832.000	6`319.333
Investment for collection and transportation (trucks, furniture and fixtures, unforeseen, others)	8`615.833	717.986
Collection, classification and packaging (leasing, stationery, wages, personal protection items, others)	54`578.410	4`548.200
Sub total	139`026.243	11`585.519

Table 4: Operating Costs Recovery Plan - Turbaco. 2016

3) *Rent for Commercialization of Usable RS:* Based on the number of usable RS and the prices they have in the market, we proceeded to prepare the financial calculation of the revenues that will be captured by the commercialization of the same. It is clarified that the value of the paper and cardboard varies depending on whether it is packed or loose, its quality (color) and volume. In the case of plastics and scrap, the price varies depending on whether it is packed or not contaminated with substances that make it impossible to recover (recycling). Table 5 shows the result of the exercise.

Type RS	Recovered (Ton/month)	Cost (Ton)	Total / month
Paper	16,62	500.000	8.310.000
File			
Magazine			
Newpaper			
Phone Guides			
Cleans			
PaperBoard	20,46	450.000	9`207.000
Kraft			
Corrugated			
Youthful			
Glass	15,81	150.000	2`371.500
Transparente			
Ambar			
Green			
Plastics	63,66		
PET		800.000	2`037.120
PEAD		0	0
PVC		1.400.000	445.620
PEBD		0	0
PP		1.600.000	2`546.400
PS		0	0
Others		0	0
Non Ferrous Scrap	0,36	2.300.000	828.000
Aluminum			
Non Ferrous Scrap	8,34	600.000	5`004.000
Total	125,25		$ 30`749.640

Table 5: RS rental income by commercialization - Turbaco. 2016

As can be observed the value of the recoverable RS according to the commercialization of the amount of sub products generated per month was $ 30`749,640. Thus the things to calculate the economic potential generated by the usable RSs used the following formula:

Economic Potential ($) = Net Sales-Selling Costs
Economic Potential ($) = $ 30`749,640- $ 11`585,519
Monthly Economic Potential ($) = $ 19`164,121
Annual Economic Potential ($) = $ 229,969,452

V. RESULTS AND DISCUSSION

The typical maximum generation of solid waste in Turbaco according to the study, amounts to 1,904.5 Ton / month which is equivalent to 63.5 Ton / day approximately. Regarding per capita generation, a population of 116,880 was considered and with this data the value obtained was 0.53 kg / inhab / day. For the determination of the physical composition, the categories described by Gallardo et al. (2006) were used as shown in Table 2. The same table shows the percentage distribution by weight of RS and by-products generated in the municipality of Turbaco. In that consideration were not considered hospital, industrial and public R & D.

It is important to emphasize that the RS of domestic origin and commercial premises, represent the largest proportion that is generated in the municipality.

Table 2 shows the physical characterization of the RS of the municipality of Turbaco from where it can be concluded that of the 63.5 Ton / day of RS that are generated, 58.34% corresponds to component to organic RS, which is equivalent to a generating 37.05 Ton / day being those that represent the largest generation. On the other hand, it is also observed that only 27, 22% are recoverable materials, which is equivalent to 17.29 Ton / day of the total.

As for RS, it is evident that of the utilizables, plastics in all its varieties represent significantly the highest percentage with a value of 12.28% which is equivalent to 63.66 Ton / month which if they were to be used, would decrease significantly the volume of the landfill and would extend the life of the landfill. Ferrous scrap (1.61%) and non-ferrous scrap (0.07%) are the lowest-value by-products, but because of their value within the economic potential exercise, they contribute significant monthly economic significance.

With respect to the profits that the exercise of economic potential showed in the amount of $ 229,969,452 a year, it can be said that there are important opportunities regarding the activity of recycling for the municipality, being able to increase in the measure that increases the projection of the population. The generation of employment and the creation of microenterprises is one of them and therefore the reduction of environmental impacts in the environment.

Added value of usable RS: One of the best options to promote good solid waste management is to promote knowledge about the economic added value they possess through the logistics chain of their recovery and transformation. In the municipality of Turbaco, there is no significant activity of recovery and recycling of materials, particularly plastics, aluminum, paper and glass. There are some locals and recyclers who engage in this activity informally. The idea that is shown with this work is the convenience that would be for the municipality to develop this activity on a large scale and with a management system that optimizes the recovery and recycling of usable RS.

For this analysis we propose a scenario in which the municipality implements an MSW management system with separation in the source in two fractions: one organic for the composting and the other inorganic that would be processed in a recovery facility of materials such as plastics, paper and paperboard, ferrous metals, non-ferrous metals, multilayer packaging and glass. This study shows the results of the economic potential and high viability of recoverable materials.

VI. CONCLUSIONS AND RECOMMENDATIONS

With regard to the physical characterization of RS in the municipality of Turbaco, it was determined by the quartering method that organic residues or biomass represent the highest percentage of physical composition with 58.34%; 12.28% plastics; 27.22% recoverable materials; 4.95% hygienic; 2.0% ceramic products, ashes, rocks and debris. This shows an important change in consumption habits and reveals the usual trend in the composition of SRs due to the greater industrialization of food. This also affects the generation of a greater proportion of plastic materials that are generally used in packaging. The percentage of diapers and toilets reveals a high consumption of this type of products. It is concluded that organic matter is the main material generated by the municipality of Turbaco, representing a high pollution problem, due to its decomposition because there is no separation plant, recycling and treatment of RS in the current landfill of the "Loma de Los Cocos".

With respect to the result of the value added of the recoverable materials, it is possible and economically attractive to recover and recycle: plastics, paper and board, aluminum and glass.

The commercialization of recovered materials could generate up to $ 229,969,452 of revenue per year. Plastics, paper and cardboard and aluminum are the most interesting materials to be recycled. In addition, Resolution 0754 of 2014, which adopts the methodology for the formulation, implementation, evaluation, monitoring, control and updating of the Comprehensive Solid Waste Management Plans (PGIRS) in Colombia.

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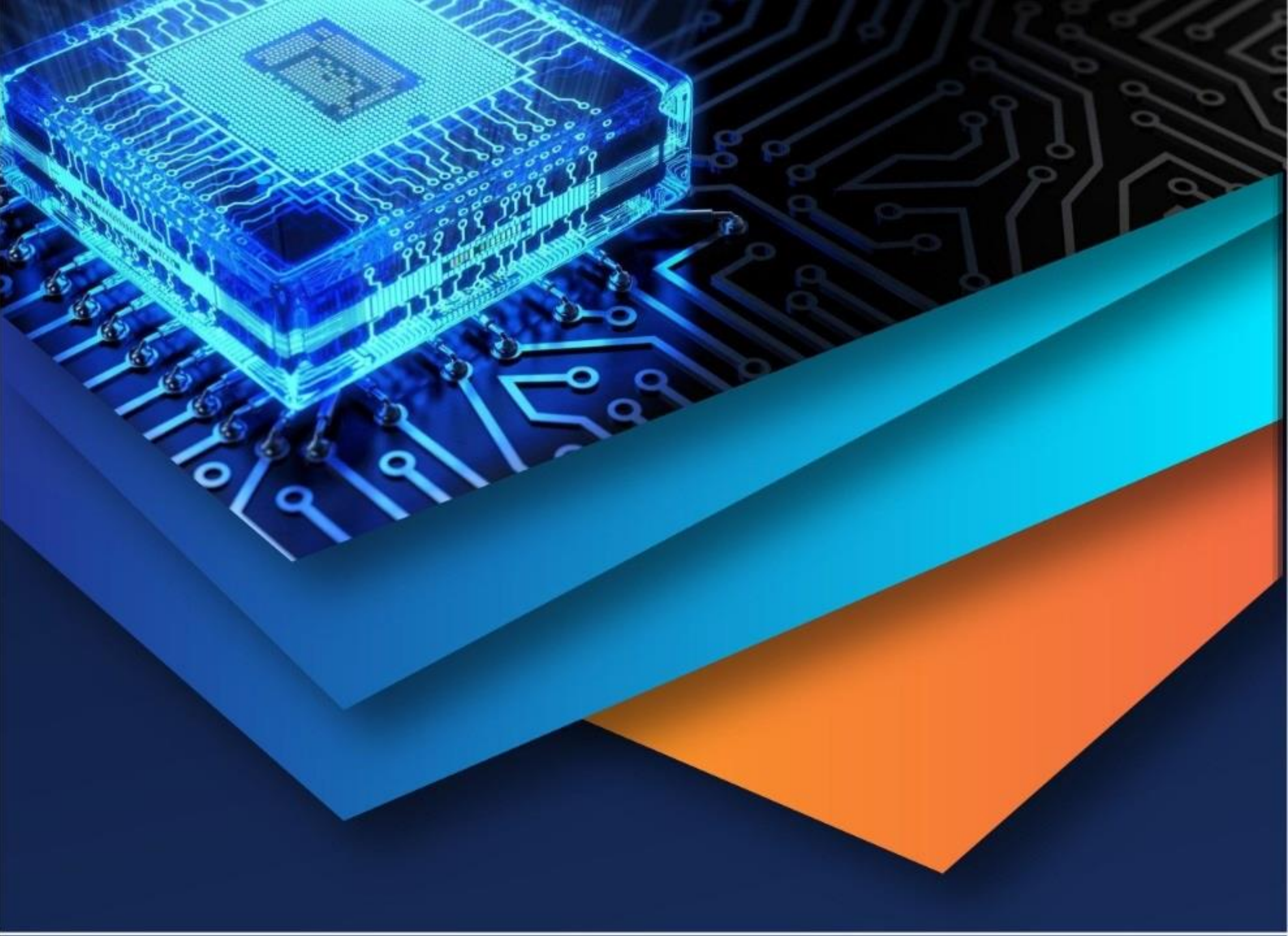

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