International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 52 No. 1 August 2025, pp. 20-31

Mechanical And Physicochemical Characterization Of A Cylindrical Tank Manufactured From Plastic Waste And Sisal Fiber

RAKOTONIRINA Jean Marcel[1], ROGE Patrick[2], RAZANAJATOVO Mariette[3]

[1]Ecole Doctorale en PHYSIQUE ET APPLICATIONS
Domaine Sciences de l'Ingénieur, Laboratoire de Physique des Solides et Physique Expérimentale (L.P.S.P.E), Université d'Antananarivo
Antananarivo, Madagascar

[2]Docteur HDR de l'Ecole Doctorale en PHYSIQUE ET APPLICATIONS
Membre de l'Equipe d'Accueil 1 : Physique des Ondes et de la Matière – Sciences Chimiques et Industrielles (POMSCI), Université d'Antananarivo
Antananarivo, Madagascar

[3]Professeur titulaire de l'Ecole Doctorale en PHYSIQUE ET APPLICATIONS Chef du département et Responsable de Laboratoire, Université d'Antananarivo Antananarivo, Madagascar

Corresponding Author: RAKOTONIRINA Jean Marcel. E-mail: rrinadoudou@gmail.com

Abstract – This study focuses on the characterization of a cylindrical tank made from plastic waste reinforced with Agave angustifolia fibers. The objective is to assess the mechanical and functional properties of the final product in order to determine its potential for practical and sustainable use. The experimental process involved material selection, cold molding, and the addition of natural fibers to enhance structural performance. An epoxy resin was used as a bonding agent between the plastic matrix and the natural fibers to improve cohesion and mechanical properties of the composite. Various tests were conducted, including mechanical strength, water tightness, and aging resistance. The results show that the additional of Agave angustifolia fibers significantly improves the mechanical properties of recycled plastic, particularly compressive strength and stiffness. The tank also demonstrates good water retention capacity and long – term durability. These findings confirm the feasibility of producing low – cost, environmentally friendly containers using a mixture of plastic waste and natural fibers. This research contributes to the valorization of plastic waste and offers sustainable solution for regions facing environmental challenges and limited access to resources.

Keywords—Composite, Mechanical Properties, Plastic Waste, Cylindrical Tank, Cold Process, Porosity.

1. INTRODUCTION

Plastic pollution now represents a major environmental concern, particularly in developing countries where waste collection and treatment systems are often inadequate. Among the various sustainable waste management strategies, the recycling and valorization of used plastics have emerged as essential solutions to limit their negative environmental impact.

In this context, numerous research efforts have focused on the reuse of plastic waste in the construction and civil engineering sectors. The incorporation of plastics into cement-based matrices [18] [19], as well as the production of tiles, bricks, or pavers from recycled materials [8], reflect the growing interest in this approach. Furthermore, certain initiatives, such as that of Traoré Brahiman have demonstrated the potential of plastic waste in road infrastructure applications [1].

The present research aligns with this trend of plastic waste valorization by proposing an innovative approach based on finely ground thermoplastic and thermosetting plastic waste of uniform particle size, combined with natural sisal fibers. The objective is to design and fabricate a cylindrical tank using a cold molding process. This method offers the advantages of being simple, low-cost, and particularly well suited to low-resource settings, while also reducing the energy consumption associated with traditional manufacturing methods.

The aim of this study is to analyze the mechanical properties of a cylindrical tank made from recycled materials and to evaluate the combined effect of the proportion of thermoplastic plastics and sisal fibers on its strength. It also seeks to demonstrate the technical feasibility of such a process, providing experimental data that could support potential replication at an industrial or community scale.

2. MATERIALS AND METHODS

2.1 Raw materials :

The composite material investigated in this study is composed of three main constituents:

- Plastic waste
- Sisal fiber
- Epoxy resin

2.1.1 Plastic waste :

Plastic waste originates from various local sources such as household, medical, industrial, and artisanal waste. These wastes include thermoplastics such us polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC), as well as thermosetting plastics derived from epoxy resin residues or unsaturated polyester, originating from old composite materials or hardened part shells.

In the present study, plastic waste serves as the primary matrix of the composite, ensuring cohesion of the mixture and transmission of mechanical stresses. It also contributes to the structural strength and water tightness of the tank, while promoting the valorization of plastic waste.

2.1.2 Sisal fiber :

Sisal fiber is a strong filamentous material of plant origin, extracted from the leaves of "*Agave angustifolia*", a plant native to Mexico. This plant was selected due to its adaptability to a wide range of soil types, making it a renewable and widely available resource. Characterized by its strength and durability, sisal fiber is commonly used as reinforcement in composite materials. It also represents an eco-friendly and cost-effective alternative to fiberglass.

In this study, sisal fiber was employed as a substitute for aramid and asbestos fibers in the design of a cylindrical tank. This choice aims to leverage the mechanical and environmental benefits offered by this natural fiber while ensuring adequate performance for the intended application. Figure 1 shows the image of the Agave angustifolia plant, from which the fiber used in study was extracted.

Fig.1 : Agave angustifolia

2.1.3 Epoxy resin :

In this study, epoxy resin was used as the primary binder in the fabrication of the composite. This thermosetting resin is a two-component system consisting of an epoxy base and a hardener. It was selected for its ability to cure at room temperature, its strong adhesion to granular plastic and sisal fibers, as well as for its excellent mechanical and chemical properties. The epoxy resin plays a central role in ensuring the cohesion of the final composite.

2.2 Equipments :

In this study, a manually operated mixing mold with a parallelepiped shape was developed, specifically designed to ensure the homogeneity of the raw materials. Additionally, a cylindrical mold of known dimensions, made from black steel sheet metal, was used as the primary mold for shaping the cylindrical tank. The technical sketches of these devices are presented below in figures 2 and 3.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 52 No. 1 August 2025, pp. 20-31

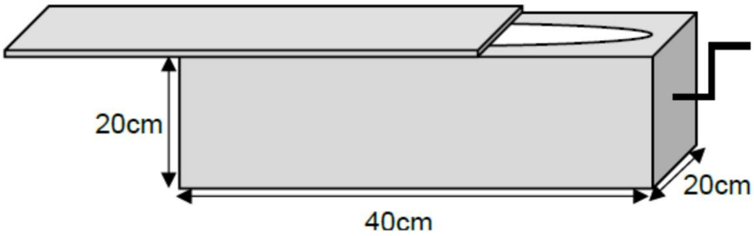

Fig.3 : Mixing mold

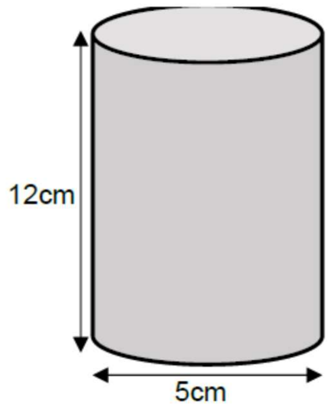

Fig.2 : Shaping mold

2.3 Methods :

The methodology adopted for the design and production of the cylindrical tank using plastic waste and sisal fibers is structured into several successive stages. To ensure clarity and coherence, these stages are organized into two main phases:

- Preparatory phase
- Fabrication and characterization phase

Each phase is presented separately and summarized through a synoptic diagram, providing a clear overview of the methodological approach.

Figure 4 presents the synoptic diagram of the preparatory phase, which includes the preliminary steps such as material selection and preparation. Figure 5 illustrates the production and characterization phase, encompassing the fabrication of the tank and experimental tests performed to evaluate its properties.

Fig.4 : Synoptic diagram of the preparatory phase

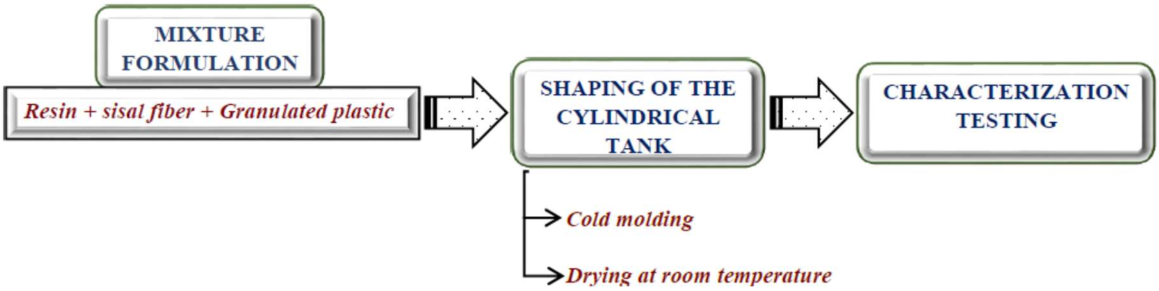

Fig.5 : Synoptic diagram of the production and characterization phase

After completing the preparatory phase (sorting, cleaning, and shredding of plastic waste, and cutting of sisal fibers), the cylindrical tank was designed and cold fabricated. In a manually operated mixer, epoxy resin was first blended with natural sisal fibers to ensure proper impregnation. Recycled plastics in the form of granules were then added, and mixing is continued until a homogeneous and properly proportioned mixture is obtained. This mixture was then poured into a cylindrical mold previously lined with Kraft paper to prevent adhesion of the composite to the mold walls. The molding was left to cure at room temperature for 24 hours.

As part of the experimental procedure, six (06) different plastic proportions were tested to identify the optimal composition of the mixture. For each proportion, five (05) replicates were performed to ensure the reliability of the results and to verify the reproducibility of the formulation. The results presented correspond to statistical averages derived from these five repetitions.

A series of physicochemical analysis was subsequently carried out to evaluate the performance of the resulting composite material. Mechanical tests on the samples including compressive strength and hardness were conducted using a universal testing machine at a private civil engineering laboratory to assess the mechanical properties of the fabricated product. Physical tests such as water tightness and porosity were performed using direct calculation methods based on experimental observations. In addition, Thin Layer Chromatography (TLC) analysis was conducted in a chemistry laboratory to detect any potential residual toxic compounds originating from the recycled plastics.

3. RESULTS AND DISCUSSION

3.1 Sample dimensions :

Figure 6 below shows the visual outcome of the experiment on the design of cylindrical tank samples produced from the cold-mixed blend of resin, sisal fiber, and plastic waste.

Fig.6 : Sample of the cylindrical tank

The dimensions of the cylindrical tank obtained are presented in the table below:

Table 1 : Dimensions and physical quantities of the cylindrical tank samples

		Notations	Unit	Values
PHYSICAL QUANTITIES	Thickness	e	$[cm]$	0,5
	Inner diameter	d	$[cm]$	5
	Outer diameter	D	$[cm]$	6
	Inner height	h_c	$[cm]$	11,5
	Outer height	H_c	$[cm]$	12
	Outer lateral surface	$S_r(e)$	$[cm^2]$	264
	Theoretical volume	V_{th}	$[cm^3]$	136,714
	Inner lateral surface	$S_r(i)$	$[cm^2]$	216,857

These dimensional measurements make it possible to quantify the values of various physical quantities related to the characterization of the cylindrical tank sample fabricated from the resin, sisal fiber, and plastic mixture. The table below presents the results concerning the dimensions and the values of the physical quantities of the fabricated cylindrical tank.

3.2 Average mass and volume values:

3.2.1 Average mass values :

Table 2 presents the experimental result of the average mass values of the cold-formed tank samples as a function of the plastic mass proportion.

Table 2 : Experimental mass of the tank sample as a function of the plastic mass fraction

Mass fraction of plastic (%)	30	31	32	33	34	35
Experimental mass (g)	230,86	230,92	230,96	230,99	231,01	231,04

This table states of the average experimental mass values of the samples fabricated by the mixture of resin and sisal fiber slightly increase with the mass proportion of plastics. This slight variation is attributed to the density of the dry materials use during the fabrication process.

3.2.2 Average volume values:

Table 3 shows the experimental result of the average volume values of the cold-formed cylindrical tank samples as a function of the mass percentage of plastics.

Tableau 3 : Experimental volume of tank samples as a function of the plastic mass proportion

Mass proportion of plastic (%)	30	31	32	33	34	35
Experimental volume (cm^3)	136,603	136,639	136,662	136,680	136,692	136,70

These results show that the differences between the average experimental volume values of obtained samples are small. These small differences can be explained by the presence of a small void fraction inside the manufactured thanks.

3.3 Physical property of the sample:

3.3.1 Water absorption :

Figure 7 shows variation curve of the water absorption coefficient of cylindrical tank as a function of the plastic mass proportion used during characterization tests performed on samples obtained from the cold design process.

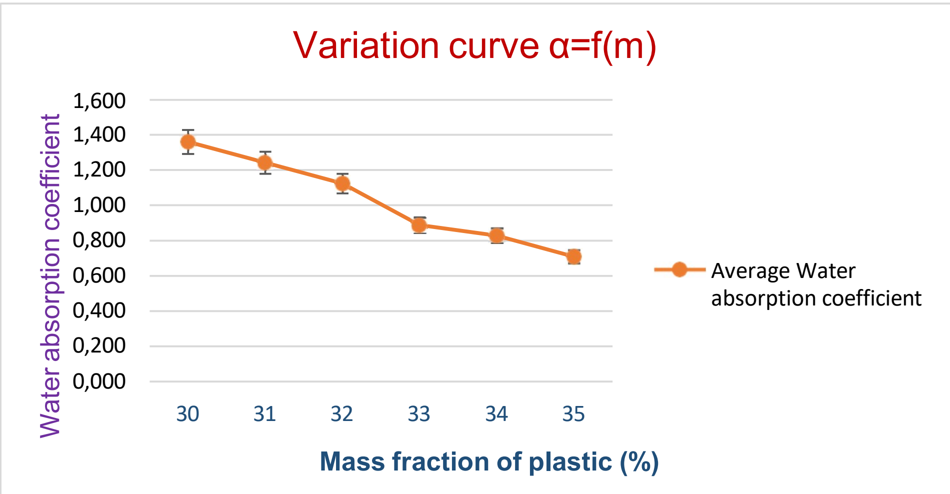

Fig.7 : Variation of the water absorption coefficient as a function of plastic proportion

The variation curve of the water absorption coefficient of the tank as a function of the mass fraction is decreasing. It highlights that the water absorption values of the control cylindrical tank vary from 1,361% to 0,710%.

This result shows that water absorption coefficient of the manufactured sample from the mixture of epoxy resin, sisal fiber and plastics decreases as the mass fraction of the material increases.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 52 No. 1 August 2025, pp. 20-31

According to the European standards NF EN 1338 on weather resistance of composite materials, the required performances in terms of water absorption must be less than or equal to 6%. In this experimental study, these performances range between 1,361 and 0,710.

3.3.2 Porosity :

Figure 8 shows the average variation in porosities the designed tank samples as a function of the plastic mass fractions.

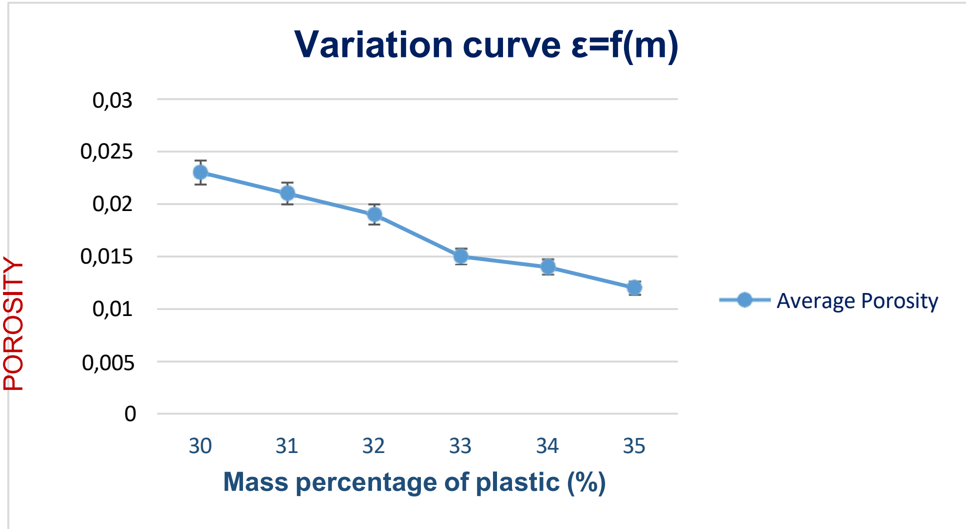

Fig.8 : Variation of porosity as a function of the mass percentage of plastic

The variation curve of porosity is decreasing and it has same slope as the water absorption curve. This result shows that the porosity of cylindrical tank samples is proportional to water absorption coefficient.

The porosity of manufactured cylindrical tank varies from 0,023 to 0,012. This progressive decrease in porosity throughout the tests indicates improved in the compactness of the fabricated tank. These results in improved leak tightness enhanced mechanical strength, and greater material durability representing a significant advantage for structural and storage applications.

3.3.3 Density :

Table 4 presents the result of apparent density values of the manufactured control samples as a function of the mass proportion of the plastic waste used.

Table 4 : density of cold cylindrical tank samples

Plastic content (%)	**30**	**31**	**32**	**33**	**34**	**35**
Density	1,690	1,690	1,690	1,690	1,690	1,690

These results confirms that the apparent density of the cold-designed samples remains constant between 30% to 35% plastic mass fractions. This invariance can be explained by a compensation between the specific densities of the components, as well as a relatively stable porosity resulting from the manufacturing process. Indeed, the lightweight fibers and the resin, well distributed within the plastic matrix, did not significantly alter the overall volume of the composite. It is also likely that the proportions used did not reach a critical threshold to influence the overall bulk density. This density stability is an asset for ensuring the homogeneity of the designed tank.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 52 No. 1 August 2025, pp. 20-31

3.4 Mechanical properties of the sample:

3.4.1. Compressive strength

Figure 9 presents the variation curve of maximum compressive strength supported by the samples as a function of the plastic mass fraction.

On the mixture of 30% to 33% of plastic wastes, the resultant of the compressive forces per unit area

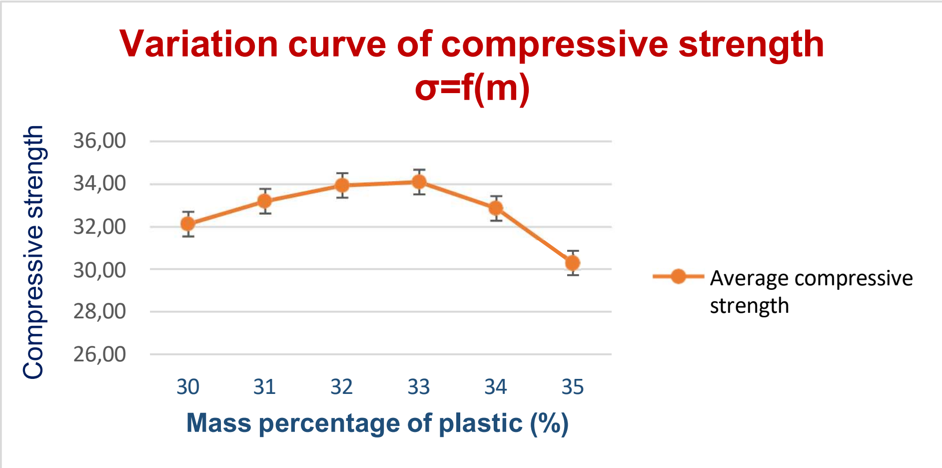

Fig. 9 : Variation of compressive strength as a function of plastic mass fraction

sustained by the control tanks made from a mixture of resin, sisal fiber and plastic increases by 32,13MPa until reaching the maximal pressure of 34,10MPa. After this augmentation, it gradually decrease of 32,86MPa to 30,28MPa.

These results shows that the compressive strengths reach their maximum when the mass value is 33%.

3.4.2. Internal pressure resistance of the sample:

Figure 10 represents the maximal values of internal pressure sustains by the samples developed as a function of mass percentage of plastic.

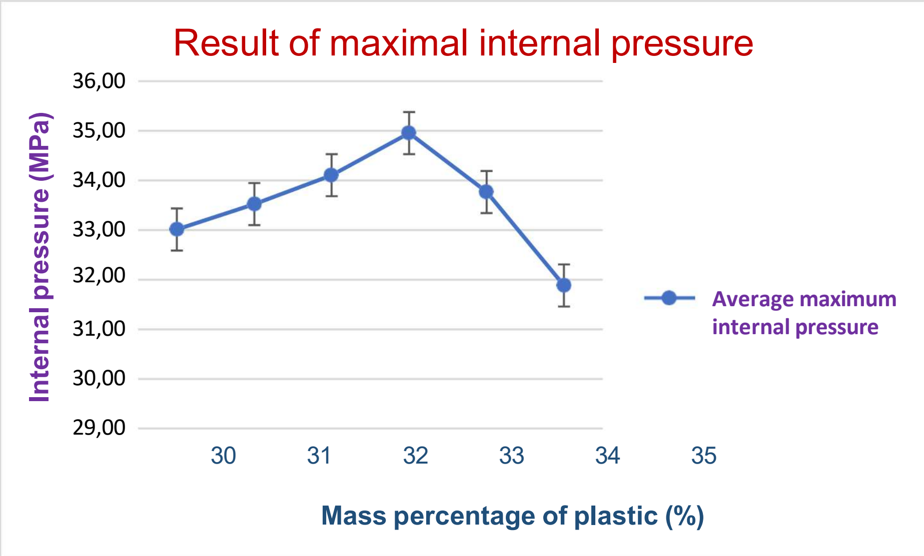

Fig.10 : Variation of internal pressure strength as a function of the plastic content

This result shows that the resultant of the destructive pressure forces sustained inside a manufactured cylindrical tank is always greater than resultant of compressive forces supported by the tank. The maximum destructive pressure sustained inside the samples increase from 33,01MPa to 34,95MPa when the mass percentage of plastic vary from 30% to 33% and beyond 34% of plastics, these pressure gradually decreases from 33,77MPa to 31,88MPa.

3.5 Thin layer chromatography (TLC) :

The thin layer chromatography of control sample and distilled water left in a tank for seven days shows no stains. The chromatograms are presented in the figure 11 below.

1: Blank

2: Distilled water left in a tank for 7 days.

The chromatographic study performed the control sample and on distilled water left in a tank for seven days shows that product no is observable under UV light at the wavelength λ=254 nm and 365 nm, nor revealed by vanillin- sulfuric.

This result indicates that the distilled water play the role of the polar solvent cannot extract the components of the tank. The tank does not release any components into the polar solvent. The result can confirm that the cylindrical tank sample made from the mixture between resin, sisal fiber, and plastic contain no toxic product.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 52 No. 1 August 2025, pp. 20-31

Revealed with vanillin　　Observe under UV light with λ= 254 nm　　Observe under UV with λ= 365 nm

Fig.11 : Thin layer chromatography

4. CONCLUSION :

This study enabled the cold design and fabrication of an innovative cylindrical tank made from plastic waste, reinforced with natural sisal fibers and bound with epoxy resin. The experimental results, including mechanical and physicochemical tests, demonstrated that the final product exhibits satisfactory performance, particularly in terms of compressive strength, leak resistance, density, porosity, and durability. The incorporation of sisal fibers significantly enhances the mechanical behavior of the tank, indicating that natural reinforcement can be effectively used in composite materials for structural application.

Furthermore, the valorization of plastic waste in context contributes to an environmentally responsible and sustainable approach to material reuse. This initiative not only addresses the growing issue of plastic pollution but also proposes a practical and affordable solution for manufacturing basic equipment in resource – limited setting.

Despites some limitation related to manual processing and sample size, this works lays the foundation for future developments. Further, investigations are encouraged to optimize the manufacturing process, test large-scale prototypes, and explore other natural fiber reinforcements; overall, this research represents a promising step towards green engineering and circular economy initiative.

REFERENCES

[1] T. BRAHIMAN, Elaboration et Caracterisation d'une Structure Composite (sable et dechets plastiques recycles) : Amelioration de la Resistance par des Charges en Argiles., Bourgogne, 2018.

[2] R. D. C. Cathal McNaughton, *Etat des Plastiques,* 2018.

[3] W. B. Dalberg, «Pollution Plastique a qui la faute ?,» 2019.

[4] O. S. Gilles DOUBLIER1, Valorisation des déchets de sachets plastiques, Bourkina Faso, 2009.

[5] S.-C. Jean-Christophe, synthèse de polymères thermoplastiques énergétiques riches en azote, Montreal.

[6] M. Hutchinson, Vos dechets et vous, Quebec: Multimondes.

[7] B. J. e. D. JM, Propriete Mecanique des Materiaux, Montréal, Presse internationale polytechnique.

[8] R. R. J. d. D. M. M. Rijalalaina, «Valorisation à l'échelle pilote des déchets plastiques pour la fabrication de matériaux de construction,» vol. 2, 2014.

[9] PAUL, *Différents types de Matières plastiques,* Cap Science, 2006.

[10] P.E.P, «Les Propriétés des polymères et des composites,» 2005.

[11] P. Nicaud, *LES MATIERES PLASTIQUES.*

[12] C. WD, Science et génie des matériaux, Dunod.

[13] R. R. (Ed.), Sisal: Agronomy,Production, and Application, New york: Nova Science publishers, 2017.

[14] J.-P. Pascault, Les polymères: Structure, Propriétés, Applications, Paris: Dunod, 2006.

[15] M. Biron, «Matériaux composites à matrice polymère,» 2e éd,Elsevier - Masson, Paris, 2014.

[16] F. L. Mantia, «Handbook of Plastic Recycling,» ChemTec Publishing, Toronto, 2002.

[17] V. Goodship, «Recycled Plastic in Construction,» Woodhead Publishing, Cambridge, 2020.

[18] B. H. ABDELLI Zakaria, «Les effets des déchets de plastique réemployés sur le tranfert d'humidité en phase liquide d'un mortier cimentaire,» 2023.

[19] B. Samir, «Valorisation et recyclage des déchets plastiques dans le béton,» Algérie, 2014.