THE UTILIZATION OF SLUDGE WASTE MIXED WITH OLD NEWSPRINT AND ABACA FIBERS AS RAW MATERIAL FOR PULP/PAPER MANUFACTURE

(Pemanfaatan Campuran Limbah Sludge, Kertas Koran Bekas, dan Serat Abaka sebagai Bahan Baku Pembuatan Pulp/Kertas)

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ABSTRAK

Industri pulp/kertas Indonesia kebanyakan masih tergantung pada kayu konvensional. Salah satu mengurangi ketergantungan ini adalah mencari sumber serat ligno selulosa lain yang dapat dimanfaatkan seperti: limbah sludge, kertas koran bekas, dan serat abaka (*Musa textiles Nee*), sebagaimana dilakukan dalam percobaan ini menjadi pulp untuk kertas karton. Mula-mula, sludge dibersihkan sehingga bebas dari bahan asing berukuran relatif besar, kertas bekas dibuang tintanya dan diolah menjadi pulp, dan kulit batang abaka diolah menjadi pulp dengan proses semi-kimia soda panas. Selanjutnya, bubur serat disiapkan dengan variasi komposisi campuran sludge bersih (0 - 30 persen), pulp koran bekas (55 - 100 persen), dan pulp abaka (0 - 15 persen). Pada tiap komposisi tersebut, ditambahkan bahan aditif (alum pengikat dan perekat pati, masing-masing 1,5 persen). Selanjutnya, lembaran pulp dibentuk secara manual bertarget gramatur 125 gram per m², dan diuji sifat kekuatan dan derajat kecerahannya.

Hasil percobaan menunjukkan bahwa menurunnya porsi sludge, dan meningkatnya pulp kertas koran bekas ataupun pulp abaka meningkatkan kekuatan lembaran pulp. Derajat kecerahan lembaran pulp juga mengalami hal serupa, tetapi menurun dengan meningkatnya porsi pulp abaka. Kualitas lembaran pulp campuran dari 0-10 persen sludge berserat pendek, 75-100 persen kertas koran bekas, dan 0-15 persen pulp abaka dapat menyamai kertas karton komersial bergramatur 125 gram per m². Penggunaan sludge lebih dari 10 persen masih mungkin dengan pemakaian lebih banyak bahan pengikat/perekat (pati, dekstrin, dan resin).

Kata kunci: Kertas koran bekas, limbah sludge berserat pendek, kulit batang abaka, kertas karton, dan pulp.

ABSTRACT

Pulp/paper industries in Indonesia mostly still depend on the conventional wood. Therefore, other ligno-cellulosic fiber stuffs should be introduced, e.g. sludge waste, old/used

newsprint, and fiber-bearing abaca (*Musa textiles* Nee) plant sheath, as experimented into pulp for paperboard. At first, the sludge was cleaned of impurities, old newsprint deinked and repulped, and abaca sheaths cooked with hot-soda semi-chemical process into unbleached pulp. Several pulp furnishes were prepared by blending of impurity-free sludge (0 – 30 percent), old-newsprint pulp (55 – 100 percent), and unbleached abaca pulp (0 – 15 percent). Additive agents (i.e. alum's retention aid and starch's binding agent each at 1.5 percent) were introduced to every furnish. Afterwards, hand-made pulp sheet with the targeted 125 gram per m² basis weight was prepared from each of the additive-introduced furnishes, and then its strength and brightness examined.

Lower portion of sludge, and higher portions of old-newsprint pulp as well as abaca pulp increased the strengths of pulp sheet. Sheet brightness experienced similarly, but it decreased with higher portion of abaca pulp. The qualities of the pulp sheet containing 0–10 percent short-fiber sludge, 75–100 percent old-newsprint pulp, and 0 – 15 percent long-fiber abaca pulp corresponded approximately to those of commercial paperboard with 125 gram per m² basis weight. Yet, sludge use greater than 10 percent was still possible by incorporating more portion of binding agents (e.g. starch, dextrans, and resins).

Keywords: Old newsprint, short-fibered sludge, long-fibered abaca sheaths, commercial paperboard, and pulp furnishes

I. INTRODUCTION

In Indonesia, the availability of wood materials as the conventional fiber source for pulp/paper industries has become the main concern in this perspective. The dependency of these industries on wood has triggered the destruction of natural forest (Anonim, 2001) and hence enforced the related entrepreneurs to seek other alternative fiber sources, which should be cheap, easy to procure, and fulfill the pulp/paper quality requirements. Among those that can be proposed are old/discarded newsprint, sludge wastes, and abaca fibers.

Indonesia's consumption of newsprint apparently tended to increase in the last 5 years (1995 – 2001), thereby generating abundant amount of used/old newsprint (Anonim, 2001). Hence, it can be worth that the old newsprint wastes are re-processed into pulp/paper items.

The sludge waste as generated by a pulp/paper mill which employs kraft process normally reaches 200 – 300 tons per day with about 70-percent moisture content. The disposal or incineration of sludge becomes increasingly difficult due to more stringent environmental constraints (Mabee, 1999). Sludge can consists of short fibers, fines, filler, and other additive agents. Therefore, the utilization of sludge as fiber source for pulp/paper can be potential. Unfortunately, such utilization in Indonesia is not yet optimal, and hence immediate action is necessary to cope with it.

Abaca fibers, often called as Manila hemp, are prepared from the outer sheath of the stems of the banana plant (*Musa textiles* Nee) species. Abaca can be considered as a source of long fibers, because their length ranges 1 - 12 mm, averaging about 6 mm. The content of cellulose is relatively high, i.e. approximately 64.7 percent (Stephenson, 1952). Further, abaca plants are fast-growing annual fiber crops with a high fiber yield per particular area (i.e. 1.4 – 2.8 dry metric tons per acre per year) and grow abundantly in tropical regions, including Indonesia (Haroen, 1999; and Torres, et. al., 1997). All the

briefly described characteristics can make fiber-bearing abaca sheaths a versatile and outstanding raw material alternative to wood-based pulps.

In relevant to the all briefly described constraints, this paper deals with laboratory-scale pulp/paper-experimental results using non-wood (i.e. secondary as well as virgin) fibers, i.e. old newsprint, sludge wastes, and abaca fibers, with the details forthcoming.

II. MATERIALS AND METHOD

A. Raw Materials

Raw materials consisted of fiber-bearing abaca sheaths, old newsprints, and sludge waste. Sample of abaca sheaths was supplied from their plantation sites, situated in Sukabumi. Meanwhile, old newsprint was collected from the garbage sites in Bogor. Further, the sludge was obtained from pulp/paper mill employing the kraft process, located in Banten.

B. Preparing the Sludge

The sludge waste was thoroughly washed, and then manually separated/cleaned of its large-size impurities, such as sand particles, rubber, and other visible dirt. The washed impurity-free sludge was further centrifuged to decrease considerably its moisture content. A sample of the centrifuged sludge was taken, and the remainder to be used in the further experiment. From the sample was determined the recovery/yield of impurity-free sludge.

C. The Pulping of Fiber-bearing Abaca Sheaths

The abaca sheaths were cut into approximately 5-cm length and then semi-chemically pulped using atmospheric hot-soda process. At first, the sheaths were cooked in 8-percent NaOH at 100°C for 2 hours with material-to-liquor ratio of 1:8. Afterwards, the cooked sheaths were thoroughly washed and then refined in a disk refiner using a clearance gap at 0.005 inches to produce abaca pulp at approximately 700 ml CSF. A particular amount of the resulting abaca pulp was taken for the determination of its screened yield and rejects. The remaining pulp was further refined in a Niagara beater to reach 275 – 300 CSF, and then kept for further experiment.

D. Reprocessing of Old Newsprint into Pulp

The old newsprint was torn-off into small-size pieces, and soaked in water until saturated. The saturated pieces were put into the hydropulper, equipped with a continuous agitator. Water was added such that the consistency of the newsprint slurry in the hydropulper was 8 percent. The chemicals as also added in the hydropulper were 1-percent NaOH, 1 percent H₂O₂, 1 percent Na₂SiO₃, and 0.2 percent DTPA (2,2-Dyhydroxy-3,3,3-trichloropropionic acid) on the dry-weight of the pieces. Meanwhile, the pH of the mixture of newsprint slurry, chemicals, and water in the hydropulper was regulated at about 9, and then slowly agitated at 50°C for 2 hours. The agitation coupled with the action of chemicals caused the newsprint pieces to facilitate the repulping and deinking processes

concurrently. Afterwards, the result was thoroughly washed and then put into the Holander beater at 1-percent consistency. Surfactants, i.e. castor oil and detergent soap in small amounts, are also added to the newsprint-reprocessed pulp in the beater. Mechanical action in the beater was intended to completely disintegrate the fibrous mass bundles that might still exist in the pulp into individual fibers, while concurrently the action of surfactants to ensure the completion of deinking. After all, from the resulting pulp was taken a sample in adequate quantity also for the determination of pulp yield from the deinked and repulped old- newsprint.

E. Fractionation of the Clean Sludge, Abaca Pulp, and Newsprint-reprocessed Pulp

Some amounts of the resulting three fibrous stuffs (i.e. impurity-free sludge, the abaca pulp, and the newsprint-reprocessed pulp) were each taken and then separately subjected to the fractionated or staged sievings through 60, 80, and 100 mesh screens, respectively. Afterwards were determined the portions of each of those three fractionated fibrous stuffs which consecutively retained on 60 mesh, passed 60 mesh but retained on 80 mesh, passed 80 mesh but retained 100 mesh, and passed through 100 mesh screens.

F. Preparing Pulp Handsheet

At first, eight kinds of pulp furnishes were prepared by manipulating the mixture in particular portions of i.e. impurity-free sludge at 0 – 30 percent, old-newsprint pulp at 55 – 100 percent, and abaca pulp at 0 – 15 percent (Table 1). Each of the furnishes was further added with water to form fiber suspension (pulp slurry) at 2 percent consistency and then agitated vigorously. During the agitation, the slurry was blended with additive agents (i.e. alum's retention aid and starch emulsion's binding agent, each at 1.5 percent), and afterwards ready for handsheet formation. The pulp handsheets, with a targeted basis weight of 125 gram per m² (i.e. the one of paperboard-grade item), were prepared from each of the 8 furnishes (i.e. alum-starch-added fibrous stuffs). The pulp sheet preparation was conducted according to the TAPPI Standard procedures (Anonim, 1992). The resulting sheets were further tested also following the TAPPI procedures, which covered the real basis weight, thickness, tensile strength, tear strength, concora, ring crush, stiffness, and brightness. Such tested properties/qualities were further compared with those of the commercial 125 gram per m² paperboard grade intended for folder uses.

Table 1. The fibrous furnishes composed of impurity-free sludge, abaca pulp, and newsprint-reprocessed pulp

Tabel.1. Bahan serat yang terdiri dari sludge bebas kotoran, pulp abaka, dan pulp hasil pengolahan kembali kertas bekas

Mixing code (Kode campuran) T ²⁾	Mixed portions (Porsi campuran), % ¹⁾		
	Sludge X1	Newsprint-reprocessed pulp (Pulp hasil pengolahan kembali kertas koran bekas) X2	Abaca pulp (Pulp abaka) X3
1	0	100	0
2	10	90	0
3	20	80	0
4	30	70	0
5	0	85	15
6	10	75	15
7	20	65	15
8	30	55	15

Remarks (Keterangan): ¹⁾The mixture was based on the dry weight of the particular fibrous stuffs (Campuran didasarkan atas berat kering bahan serat); ²⁾Each of the code-designated mixture was replicated three times (Masing-masing campuran dengan kode tertentu dilakukan ulangan sebanyak tiga kali)

III. RESULTS AND DISCUSSION

A. Recovery of Fiber Stuffs

The fiber stuffs in this regard were impurity-free sludge, abaca pulp, and newsprint-reprocessed pulp; and the data on their recoveries or yields were disclosed in Table 2. The 77.21 percent recovery of fiber stuffs in the impurity-free sludge indicates that during impurity removal, approximately 22.79 percent was loss as inorganic fillers, fines, or minute fragmented fibers (Mabee, 1999). Meanwhile, the high screened yield of abaca pulp, i.e. 74.60 percent with small amount of reject (0.29 percent), in fact still corresponded to the ones commonly achieved in the semi-chemical pulping of wood or other ligno-cellulosic fiber stuffs, i.e. 65 – 70 percent. Further, the yield of newsprint-reprocessed pulp was quite high as well, i.e. 84.37 percent. Some loss, i.e. 15.63 percent could be such that the old newsprint might contain particular substances, such as ink vehicle, inorganic fillers, disintegrated fibers, and fines (Stephenson, 1952).

Table 2. Yields of fiber stuffs**Tabel 2. Rendemen bahan serat**

Fiber stuffs (Bahan berserat)	Quantities (Besaran) ¹⁾	
	Yield (Rendemen) (%)	Reject (Gumpalan tak lolos saringan) (%)
Impurity-free sludge (Sludge bersih/ bebas kotoran)	77.21	-
Abaca pulp (Pulp abaka)	74.60 ²⁾	0.29
Newsprint-reprocessed pulp (Pulp hasil daur ulang kertas koran bekas)	84.37	-

Remarks (Keterangan): ¹⁾Averages of: three replications for preparing impurity-free sludge; two replications for abaca pulp; and eight replications for newsprint-reprocessed pulp (Rata-rata dari: tiga ulangan untuk penyiapan sludge bersih; dua ulangan untuk pulp abaka; dan delapan ulangan untuk pulp hasil pengolahan kembali kertas bekas);

²⁾Screened pulp yield (Rendemen pulp tersaring)

B. Results of Fractionation

The data about the fractionation results on the three types of fiber stuffs are disclosed in Table 3. It revealed that the portion of the sludge retained on 60 mesh screen was substantially the lowest compared to those of abaca pulp and newsprint-reprocessed pulp, while the portion passing through 100 mesh screen was the highest. This indicated that the sludge could contain some considerable amounts of short fibers, fragmented fibers, fines, and inorganic compounds (Mabee 1999). On the other hand, the highest portion retained on 60-mesh screen as revealed by the abaca pulp disclosed that it was intrinsically of long fiber origins (Haroen 1999; and Torres, et. al. 1997). Further, the second-highest portion of the fractionated newsprint pulp retained on 60-mesh screen indicated that it was commonly composed largely of or manufactured from long-fiber sources (particularly softwood).

C. Properties of Pulp Handsheet

The handsheets in this regard, as described before, consisted of 8 types based on the particular mixed portions between the impurity-free sludge, abaca pulp, and newsprint-reprocessed pulp (Table 1). Analysis of variances revealed that eight various types of such mixed portions affected significantly the properties of the resulting pulp sheet (Appendix 1.a).

Table 3. Results on the fractionation of three types of fiber stuffs¹⁾**Tabel 3. Hasil fraksionasi tiga macam bahan serat ¹⁾**

Fiber stuffs (Bahan serat)	Fractionated portion (<i>Porsi hasil fraksionasi</i>) (%) ²⁾			
	Retained on 60 mesh screen (<i>Tertahan pada saringan 60 mesh</i>)	Passing through 60 mesh but retained on 80 mesh screen (<i>Los saringan 60 mesh tetapi tertahan pada saringan 80 mesh</i>)	Passing through 80 mesh but retained on 100 mesh screen (<i>Los saringan 80 mesh tetapi tertahan pada saringan 100 mesh</i>)	Passing through 100 mesh screen as fines (<i>Los saringan 100 mesh sebagai fines</i>)
Impurity-free sludge (Sludge <i>bersih/bebas kotoran</i>)	16.3	11.2	26.1	46.4
Abaca pulp (<i>Pulp abaka</i>)	46.5	24.5	9.5	19.5
Nesprint-reprocessed pulp (<i>Pulp hasil pengolahan kembali kertas koran bekas</i>)	44.1	17.0	6.4	23.4

Remarks (*Keterangan*): ¹⁾Each averaged of three replications (*Masing-masing merupakan rata-rata tiga ulangan*); ²⁾By dry weight (*Atas dasar berat kering*)

For the pulp sheet without the portion of abaca pulp, the greater the sludge portion and concurrently the lower the old-newsprint pulp, then the lower the basis weight and the thickness, as indicated by the results of honestly significant difference (HSD) range test (Appendix 1.a). Further, the regression analysis (Table 4) also confirmed that the increase in sludge portion (b1) and/or the decrease in old-newsprint pulp (b2) would lower the basis weight and thickness; and vice versa. Likewise, the HSD test disclosed similar occurrences to the pulp sheet with 15 percent abaca pulp. In general, the basis weight and thickness of the pulp sheet with 15 percent abaca pulp were greater than the ones without abaca. The regression analysis revealed as well such phenomena. The possible explanation was that the sludge stuff contained fines and minute-particle portions the greatest, which passed the 100 mesh screen after the fractionation (Table 3), compared to the old newsprint pulp and abaca pulp. Consequently, such high fine portion could substantially passed through the wire during pulp sheet formation, thereby yielding the sheet with lower thickness and basis weight significantly below the targeted 125 gram per m², in comparison with the corresponding sheet without the sludge. On the other hand, the pulp with greater portions of abaca pulp and/or old-newsprint pulp brought about the contrary results, because both pulp types contained less fine portion (Table 3).

Table 4. Analysis of regression on the properties of pulp handsheet (Y) from the furnishes containing the portions of sludge (X1)¹⁾, newsprint-reprocessed pulp (X2)¹⁾, and abaca pulp (X3)¹⁾; in the multiple regression equation³⁾
 Tabel 4. Analisa regresi sifat-sifat lembaran pulp (Y) dari bahan serat yang merupakan campuran dengan porsi tertentu: sludge (X1)¹⁾, pulp hasil pengolahan kembali kertas koran bekas(X2)¹⁾, dan pulp abaka (X3)¹⁾; menurut persamaan regresi berganda ³⁾

Properties of pulp handsheet (Sifat-sifat lembaran pulp)	Intersep (Intersept) (bo)	X1		X2		X3		(R ²) ²⁾
		b1	t-values (t-hitung)	b2	t-values (t-hitung)	b3	t-values (t-hitung)	
Basis weight (gramatur), g/m ²	130.9501	-0.1503	4.98**	0.0920	5.47**	0.0583	2.33*	0.627**
Thickness (Tebal), mm	0.5206	-0.0035	5.83**	0.0017	5.04**	0.0018	3.64**	0.649**
Tensile strength (Keteguhan tarik), kgf/15 mm	7.8851	-0.0796	10.35**	0.0359	8.30**	0.0451	7.55**	0.856**
Tear strength (Keteguhan sobek), Nm ² /g	32.0992	-0.3189	24.91**	-0.2425	1.08ns	0.3190	24.91**	0.968**
Ring crush, kgf	37.3301	-0.0227	1.162ns	-0.0213	2.197*	0.3138	11.50**	0.864**
Concora, kgf	10.7635	-0.2652	6.138**	0.0522	6.201**	0.0406	3.202**	0.698**
Stiffness (Kekakuan), gf.cm	14.4184	-0.2652	4.901**	0.2939	9.751**	0.0288	0.641ns	0.819**
Brightness (Derajat kecerahan), %GE	47.5632	-0.1008	2.665*	0.2451	9.635**	-0.1443	2.596*	0.882**

Remarks (Keterangan): ¹⁾Please refer to Table 1 (Perinciannya ada di Tabel 1); ²⁾Determination coefficient (Koefisien determinasi); * = Significant at 5% level (Nyata pada taraf 5%); ** = Significant at 1% level (Nyata pada taraf 1%); ns = Not significant (Tidak nyata); ³⁾ $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \epsilon$; b1, b2, b3 = Regression coefficient (Koefisien regresi).

For comparison, the basis weight of the pulp sheet furnished from the blending of sludge, old-newsprint pulp, and abaca pulp at particular mixed portion in accordance with mixed formulae no. 1, 2, 5, and 6 (Table 1 and Appendix 1) could correspond satisfactorily to that of the commercial paperboard-grade item intended for folder uses (i.e. 125 grams per m²). Conversely, the thickness of paperboard grade could not be used for the comparison with those of the experimental results of pulp sheet. This is because the thickness of the experimental pulp sheet was intrinsically formed concurrent with the downward deposition of fiber network on the handsheet wire by drainage. Such thickness was affected by the size (dimension) of the stuffs, i.e. the greater the quantity of fine fractions, the more chance for them to pass through the wire, thereby yielding the pulp mat with rather thinner sheet. Meanwhile, the thickness of such paperboard grade was attained after several staged manufacturing processes, involving calendering and super-calendering treatments (Klungness, 1978).

With regard to the physical/mechanical strengths of the pulp sheet (i.e. tensile strength, tear strength, ring crush, concora, and stiffness), results of HSD test revealed that the greater the sludge portion and the lower the old-newsprint pulp portion then the lower the strengths (Appendix 1.a). Again, the higher portion of sludge which contained a lot of fines could be significantly attributable to such low strengths of the resulting sheet. Fines and other minute particles could interfere fiber-to-fiber bonding during sheet formation. Further, the HSD test also proved that the strengths of pulp sheet containing abaca pulp portion (i.e. 15 percent) were entirely greater than the ones without abaca (i.e. containing only old-newsprint pulp and sludge portions). This is because abaca pulp was processed from a virgin source (fiber-bearing abaca plants), while sludge and old newsprint pulp were from secondary fiber furnishes. The regression analysis further confirmed that the increase in sludge portion and/or the decreases in old newsprint pulp as well as in abaca pulp portions brought about the resulting pulp sheet with lower strengths, and vice versa (Table 4).

The tensile strength, ring crush, and concora of the pulp sheet were entirely still below those of paperboard-grade item (Appendix 1.b). However, the tear strength and stiffness of the sheet furnished from the particular blending portion of sludge, old-newsprint pulp, and abaca pulp with the mixed formula code no. 1, 2, 5, and 6 still could correspond or fall closer to those of paperboard grade (Table 1 and Appendix 1.b).

The brightness of the experimental pulp sheet tended to lower with the increase in sludge portion and/or the decrease in old-newsprint pulp portion, and vice versa (Table 4 and Appendix 1.c). This was explainable since the sludge waste could contain not only fibrous stuffs but also other non-fiber compounds such as colloid particles, soluble solids, alum, sizing, synthetic resins, coloring matters, etc. (Mabee, 1999). Meanwhile, during the reprocessing of old newsprint stuff into pulp, chemical agents were added such as hydrogen peroxide, sodium silicate, detergent, and soda to aid the deinking and mild-bleaching process on the stuff, yielding the pulp with lighter and whiter color. Consequently, higher portion of old newsprint pulp then brought about greater brightness of the resulting pulp sheet. This situation occurred to the sheet whether it contained 15-percent abaca pulp portion or not. Further, results of HSD test (Appendix 1.c) and regression analysis (Table 4) confirmed that with the sludge portion held constant the increase in abaca pulp portion accompanied or not by the decrease in old-newsprint pulp

brought about the lowering of the pulp brightness. This is because the abaca pulp which was yielded using semi-chemical soda process was still inherently unbleached.

The overall brightness of the resulting pulp sheet was in the range of 53.59 – 62.46 percent GE, and further still regarded as satisfactory for the ones resulting from the furnishes incorporating the deinked old newsprint pulp (Stephenson, 1952), and yet added with sludge and unbleached abaca pulp. In comparison with the brightness of the paperboard grade item (Appendix 1.c), those of the entire experimental pulp sheet were significantly higher. However, such comparison was not fair, because during the processing of such paperboard, the additive agents, particularly coloring matters had been incorporated.

To wrap-up, incorporating the blended fiber furnishes of short-fiber sludge portion up to 10 percent, old-newsprint pulp at 75 – 100 percent, and unbleached long-fiber abaca pulp at 15 percent revealed encouraging prospects for the pulp/paper manufacture intended for paperboard-grade item. This is confirmed through the results of HSD range test which was further followed by the HSD-based scoring evaluation. In this regard, the greatest total scores of the particular paper sheet furnished from the blending formulae with code no. 1, 2, 5, and 6 (Table 1 and Appendix 1), which were pertinent to their corresponding characteristics/ properties, indicated their most satisfactory results. The total score which excluded the scores of both thickness and brightness, however, still revealed the similar phenomena; and this regard corresponded or fell closer to those of paperboard stuff or control (Appendix 1.c).

IV. CONCLUSIONS

A laboratory-scale endeavor apparently managed to utilize efficiently sludge waste, old newsprint, and abaca pulp as the blending fiber furnishes for the manufacture of pulp/paper intended for paperboard-grade stuff. In this regard, the sludge waste should be at first treated into impurity-free fiber stuff with recovery at 77.21 percent; old newsprint to be deinked and repulped yielding the pulp at 84.37 percent; and fiber-bearing abaca sheaths to be semi-chemically treated with soda process at 74.60 percent yield. Such figures seem quite enhancing or encouraging by considering that the pulping of the conventional wood using chemical and semi-chemical process normally yields the pulp at 60 – 75 percent. The fiber furnishes in this regard consisted of 8 various mixed/blended manipulations which incorporated particular portions of impurity-free sludge up to 30 percent, old-newsprint pulp at 70 – 100 percent, and abaca pulp at 0 – 15 percent. The furnishes were each transformed into pulp handsheet with the targeted 125 gram per m² basis weight. The real basis weight of the sheet containing 30 - 40 percent sludge was about 121.36 – 122.96 gram per m², indicating that the loss of fiber stuffs during sheet formation was quite small (i.e. 1.63 - 2.91percent). This revealed the efficiency in the use of starch binding agent as incorporated in the fiber furnishes prior to sheet formation, despite the fact the sludge contained the highest fine or minute particle portion, compared to the old-newsprint pulp and abaca pulp, as indicated from the results of fiber fractionation.

The fiber furnished with the greater sludge portion and/or the less old-newsprint pulp as well as the less abaca pulp portions tended to produce pulp sheet with lower thickness and lower physical mechanical strengths (i.e. tensile strength, tear strength, concore, ring crush, and stiffness), and vice versa. Such situation almost similarly applied to the pulp brightness, with the exception that the greater the abaca pulp portion then conversely the lower the brightness. Analysis of regression also confirmed all the resulting phenomena, indicating its usefulness to predict or assess the possible changes in pulp/paper properties brought about by the changes in each of the three implemented variables (i.e. sludge, old-newsprint pulp, and abaca pulp portions) concurrently or any of the other two variables held constant.

The total-scoring system which manipulated the statistical analysis to evaluate the entire properties of pulp sheet indicated that those of the sheet that contained short-fiber sludge at 0 – 10 percent, old-newsprint pulp at 75 – 100 percent, and long-fiber abaca pulp at 0 – 15 percent brought out the greatest scores and could correspond or fall closer to the ones of the control (paperboard stuff). This also revealed that the use of up to 10-percent sludge exhibited encouraging-results. Yet, the use of sludge greater than 10 percent was still possible by incorporating more portion of binding agents (e.g. starch, dextrin, and resins) and/or greater portion of abaca pulp. To sum-up, this laboratory-scale endeavor seems quite encouraging in utilizing short-fiber sludge, old newsprint, and abaca long-fibers in all as non-wood alternatives for pulp/paper, and therefore deserves thorough continuation efforts.

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Appendix 1.a. Properties of pulp handsheet, followed by results of F-test and honestly significant difference (HSD) range test (expressed in grades and scores)

Lampiran 1.a. Sifat-sifat lembaran pulp, diikuti dengan uji F dan uji jarak beda nyata jujur/BNJ (dinyatakan dalam mutu dan skor)

Mixed Formulae (Kode campuran) (T) ⁴⁾	Properties (Sifat)								
	Basis weight (Berat dasar) (gr/cm ²)			Thickness (Tebal) (mm)			Tensile strength (Keteguhan tarik) (kgf/15 mm)		
	M ¹⁾	G ²⁾	Si ³⁾	M ¹⁾	G ²⁾	Si ³⁾	M ¹⁾	G ²⁾	Si ³⁾
1	125.17	a	4	0.329	bc	3.5	3.08	cde	2
2	125.46	a	4	0.341	ab	4.5	3.24	cd	2.5
3	122.96	b	3	0.292	d	2	2.36	e	1
4	121.36	c	2	0.285	de	1.5	2.56	de	1.5
5	125.17	a	4	0.381	a	5	4.20	b	4
6	125.10	a	4	0.333	b	4	3.68	bc	3.5
7	124.20	ab	3.5	0.306	bcd	3	3.18	cde	2
8	123.98	ab	3.5	0.337	b	4	2.92	cde	2
C ⁵⁾	125.00	a	4	0.254	-	-	6.92	a	5
F-value (F-hitung)	38.83**			26.63**			76.91**		
D0.05	1.306			0.0408			0.8747		
CV (%)	4.26			3.24			6.19		

Remarks (Keterangan): Averages of three replications/Rata-rata tiga ulangan; ²⁾Figures (Angka-angka (in the M column/dalam kolom M) accompanied horizontally with the same letters/ yang diikuti secara horisontal oleh huruf-huruf yang sama (in the G (Grade/Mutu) column/kolom) are not significantly different/tak berbeda nyata: a > b > c > d > e > f > g (based on the HSD test/atas dasar uji BNJ); ³⁾The greater the score/Semakin besar skor (S), the better the criteria of evaluating/semakin baik kriteria penilaian: basis weight (berat dasar), thickness (tebal), strength properties (sifat kekuatan), and brightness of the pulp sheet (dan derajat kecerahan lembaran pulp); D0.05 = critical value for the HSD range test/Nilai kritis untuk uji jarak BNJ; ⁴⁾T = for the details please refer to Table 1/Untuk perinciannya lihat Tabel 1; ⁵⁾C = Control/Pembanding (paperboard-grade item/kertas karton komersial), for the comparison/untuk pembandingan; * and/dan ** = significant at consecutively/nyata pada berturut-turut 5% and 1%; CV = Coefficient of variation/Koefisien keragaman.

Appendix 1.b. Properties of pulp handsheet, followed by results of F-test and HSD range test (expressed in grades and scores) – (Continuation)

Lampiran 1.b. Sifat-sifat lembaran pulp, diikuti dengan uji F dan uji jarak beda nyata jujur/BNJ (dinyatakan dalam mutu dan skor) – (Sambungan)

Mixed formulae (Kode campuran) (T) ⁴⁾	Properties (Sifat)								
	Tear strength (Kekuatan sobek) (Nm ² /g)			Ring crush (kgf)			Concora (kgf)		
	M ¹⁾	G ²⁾	Siv ³⁾	M ¹⁾	G ²⁾	Sv ³⁾	M ¹⁾	G ²⁾	Svi ³⁾
1	8.06	e	3	4.68	b	5	6.51	c	3
2	6.43	f	2	3.74	cd	3.5	6.99	b	4
3	6.33	f	2	2.95	f	1	5.05	e	1
4	5.99	g	1	3.42	de	2.5	5.15	e	1
5	11.72	a	7	4.04	c	4	6.75	b	4
6	10.97	b	6	4.55	b	5	6.95	b	4
7	9.43	d	4	3.18	ef	1.5	5.53	bc	3.5
8	9.24	d	4	3.61	d	3	6.90	d	2
C ⁵⁾	10.44	c	5	11.05	a	6	11.71	a	5
F-value (F _{hitung})	16.23**			33.35**			19.11**		
D0.05	0.3434			0.3947			0.373		
CV (%)	2.99			2.20			2.37		

Remarks (Keterangan): The same as those in Appendix 1.a (Sama seperti pada Lampiran 1.a)

Appendix 1.c. Properties of pulp handsheet, followed by results of F-test and HSD range test (expressed in grades and scores) – (Continuation)

Lampiran 1.c. Sifat-sifat lembaran pulp, diikuti dengan uji F dan uji jarak beda nyata jujur/BNJ (dinyatakan dalam mutu dan skor) – (Sambungan)

Mixed formulae (Kode campuran) (I) ⁴⁾	Properties (Sifat)							
	Rigidity (Kekakuan) (gf-cm)			Brightness (Derajat kecerahan) (%GE)			Total score (Jumlah skor) (TS)	
	M ¹⁾	G ²⁾	Svii ³⁾	M ¹⁾	G ²⁾	Sviii ³⁾	TS ⁶⁾	TS ⁷⁾
1	18.95	a	5	62.46	a	2	27.5	22
2	14.16	e	3	58.36	a	2	25.5	19
3	9.37	e	1	57.71	ab	1.5	12.5	9
4	9.09	c	1	54.71	ab	1.5	12	9
5	15.31	b	4	61.35	a	2	34	27
6	15.94	b	4	53.98	ab	1.5	32	26
7	9.16	e	1	55.74	ab	1.5	20	15
8	9.43	e	1	53.59	ab	1.5	21	15
C ⁵⁾	13.28	d	2	46.09	-	-	-	27
F-value (F-bitung)	26.63**			5.23*			-	
D0.05	0.6696			11.81			-	
CV (%)	2.33			5.34			-	

Remarks (Keterangan): (The same as above/Sama seperti di atas), with additional notation/dengan tambahan notasi, i.e. ⁶⁾The total score included the overall scores/Jumlah skor mencakup keseluruhan skor (sum of/jumlah dari: Si+Sii+ +Sviii); ⁷⁾The total score excluded the scores of thickness and brightness/Jumlah skor tidak mencakup skor tebal dan derajat kecerahan (without/tanpa Sii and/dan Sviii).