J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 3 (5): 539 - 548, 2012

SUGGESTING A COMPLETE MECHANICAL SYSTEM TO SORT HOUSEHOLD SOLID WASTES

Ismail, Nahed K.* ; M. A. Shatewy and N. M. El-Bialee***
*** Agric. Eng. Res. Inst. (AEnRI)**
**** Fac. of Agric. Eng., Al-Azhar Univ.**

ABSTRACT

This research aimed to suggest a complete mechanical system to sort household waste solid to maximize its utilization. The study carried out at four factories for recycling household solid wastes to compost at El-Dakahlia and Damietta Governorates during October 2010. The study was conducted through three stages i.e. sorting the household wastes manually, evaluating the sorting systems and suggesting a complete mechanical system for sorting household waste to minimize the refused amount of waste. From the results it can be concluded that; the manual sorting is benefit to sort the household solid wastes as quality sorting system (Zero wastes) but opposite in quantity (0.167 $Mg.h.labor^{-1}$) that was found by using the mechanical system done in the factories (0.625 – 0.977 $Mg.h.labor^{-1}$). The results explained that the two systems evaluated not enough to sort the all amount of the household wasted produced daily. Also the study cleared the re-sorted of organic mater and the wastes (refused) decreased the wastes values to 27.57 % in Beshla factory. For this reason must be suggestion the complete mechanical system consists of the adding units to the present factory to improve the waste sort quality and quantity.

INTRODUCTION

Household solid waste is the most important and dangerous types of residues facing the labor gender especially for accumulation. Despite the fact that these residues double-edged weapon. The first is environmental hazards for all elements of the environment "soil - water - air" and can cause the spread of diseases and epidemics. In Egypt, the household solid waste is about 21 $Tg.year^{-1}$ that means the daily production is about 58 Gg (http://www. dostor. org-2011). The second is if properly recycled was an important source of national income. Among the most important processes that must be done to make such waste is an important source of income, sorting process waste to separate each component separately, which are placed all components of this waste in one container. Waste composition is also influenced by external factors, such as geographical location, the population's standard of living, energy source, and weather (WHO, 1984). Arab regulator for education, culture and sciences (2003) cleared that the household solid waste in Asia south east and Africa per labor is about 0.4kg per day beside 0.7 $kg.day^{-1}$ in Asia, North Africa and South America. In the industrial cities, it's about 1.1 $kg.day^{-1}$ against 2.5 $kg.day^{-1}$ in reach cities. The important material must be separated from the household solid waste are papers, glasses bottle, plastic, aluminum, rubber and iron (http://www. uae. ii5ii. com-2010) and the center sorting of waste usually used one of the following methods; air stream, floating, rotary hammer, garble, electrostatic separation. Berg (1993) discussed how to analyses the quantity and quality of wrongly sorted materials, with the aim of evaluating the effect of sorting instructions given to the households. He also had a broader approach including data about the waste flow. Berg presented the following measurements for evaluating source sorting systems:

- Quantity of collected recyclables [kg recyclables/household or labor]
- Quality of recyclables [purity or contamination rate]
- Recycling rate [recovered material/the potential recyclable amount]
- Participation rate
- Willingness to participate
- Citizens' degree of satisfaction

www.Wekepdia.com (2012) cleared that the iron recycling can be economize used the whim iron. Also one Mg of plastic recycling economize about 0.7 Mg of crude petroleum. Adding that the recycling of one Mg of aluminum economize about 8 Mg of bokcit, 4 Mg of chemicals and 14 kWh^{-1} energy. Furthermore, one Mg carton recycling economizes 2.5 Mg wood and every one Mg of paper recycling economizes one litter of water, 2.5 kWh^{-1} and 150 g of wood. Lardinois (1993) cleared that although the quality of the compost appears to be good, it has been found to contain small pieces of glass and plastics, and large quantities of heavy metals.

Therefore, this research aims to evaluate the household solid waste sorting systems, manually and mechanically and suggest mechanical sorting system based on scientific theories to reduce the amount of refused.

MATERIALS AND METHODS

This study was carried out during October 2010 at four factories (for household solid wastes recycling to compost). These factories were located at Aga, Beshla and Sandob and Abo Greada at El-Dakahlia and Damietta Governorates, respectively. The study was conducted through three stages i.e. sorting the household wastes manually, evaluating the sorting systems and suggesting a complete mechanical system for sorting household waste to minimize the refused amount of waste. Fig. (1) shows the traditional sorting system in the most new factories which was operated in Abo Greada, Aga and Beshla factories. While, Sandob factory operated the different old system as indicated in Fig. (2).

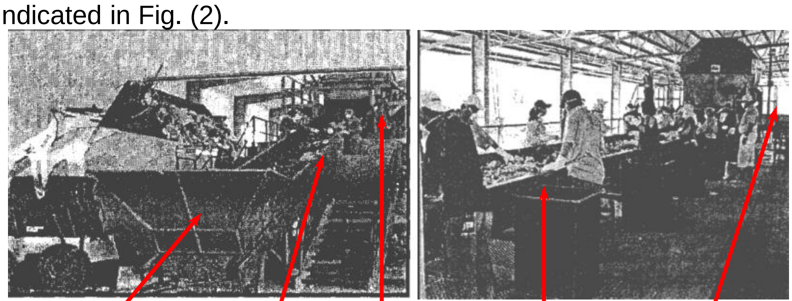

Fig. (1): Traditional household solid wastes sorting system.

Fig. (2): Old household solid wastes sorting system.

The sorting system specifications are presented in table (1). The sorting steps in the household solid waste factories are indicated in table (2).

Table (1): Sorting system specifications.

Sorting system unit	Factory name			
	Abo Greada	Aga	Beshla	Sandob
Feeding hopper capacity, Mg	0.6	0.6	0.6	0.6
Elevator belt:				
Speed, $m.s^{-1}$	0.2-0.3	0.2-0.3	0.2-0.3	0.2
Width, m	1.3	1.3	1.3	1.3
Length, m	16	16	16	20
Tilt angle, degree	18	18	18	18
Power, kW	4	4	4	4
Cutting knife: Speed, $m.s^{-1}$	0.3	0.3	0.3	0.3 and 0.2
Horizontal sorting belt				
Speed, $m.s^{-1}$	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3
Width, m	1.2	1.2	1.2	1.2
Length, m	16	16	16	16
Power, kW	4	4	4	4
Magnetic separator				
Speed, $m.s^{-1}$	1.2	1.2	1.2	1.2
Width, m	0.75	0.75	0.75	0.75
Length, m	1.2	1.2	1.2	1.2
Height, m	2.0	2.0	2.0	2.0
Power, kW	2.2	2.2	2.2	2.2
Sieving separator				
Inner diameter, m	1.8	1.8	1.8	1.8
Length, m	4	4	4	4
Hole diameter, mm	100	100	100	30 and 50
Rotating speed, $m.s^{-1}$	0.3	0.3	0.3	0.3
Power, kW	4	4	4	4

Table (2): Sorting steps in the household solid waste factories.

Sorting steps	Factory name			
	Abo Greada	Aga	Beshla	Sandob
Initial sorting	Manual	Manual	Manual	Manual
Feeding hopper loading	loader	loader	loader	loader
Elevator belt (1)	*	*	*	*
Cutting knife	*	*	*	*
Sorting belt, Labor No	8	4	8	4
Magnetic separator	*	*	*	*
Screening, sieve diameter mm	100	100	100	30
Secondary sorting, Labor No	-	-	8	-
Conveying belt	-	-	-	*
Cutting unit	-	-	-	*
Elevator belt (2)	-	-	-	-
Screening (2), sieve diameter mm	-	-	-	5

N.B: * The unit found - The unit not found

The experimental steps were done by using the one Mg of household solid waste sample for each experiment manually and mechanically. Each sample sorted by major waste component (organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other "pones, wood, brick, …etc". The mass of each component determined by weight the sample sorted. Also the total component determined by weight the sample sorted. Also the total component mass income, sorted and refused were determined to calculate the sorting efficiency.

Measurements:

1- Sorting components percent:

The sorting components were classified into eight categories i.e. organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other "pones, wood, brick, …etc". Each component mass was determined. Then, the percentage of each component was determined using the following formula:

$$Percentage\ \ of\ \ \ component = \frac{Net\ \ \ component\ \ \ mass}{Total\ \ \ sample\ \ \ mass} \times 100$$

2- Sorting system performance:

The sorting system performance as a sorting rate Mg.day^{-1} and kg.labor^{-1}.h^{-1} are determined using the following formulas:

$$Sorting\ \ rate = \frac{Total\ \ component\ \ mass\ \ generated\ \ (residual)}{Total\ \ mass\ \ dailly\ \ inlet}\ \ ,\ \ \ Mg.day^{-1}$$

$$Sorting\ \ rate = \frac{Total\ \ mass\ \ dailly\ \ generated\ \ (residual)}{Labor\ \ No\ \times\ Hourly\ \ working}\ \ ,\ \ \ kg.labor^{-1}.h^{-1}$$

3- Sorting system efficiency:

The sorting system efficiency is determined using the following formula:

$$Sorting\ \ efficiency = \frac{Total\ \ mass\ \ generated\ \ dailly}{Total\ \ mass\ \ dailly\ \ inlet} \times 100$$

Statistical Analysis:

SAS computer software package was used to employ the analysis of variance test and the LSD tests for sorting efficiency data.

Regression analysis:

Microsoft Excel 2007 computer program was used to carry out the multiple regression analysis to represent the relation between the total residual mass and both sorting time and total daily inlet mass and the relation between the total wastes (refused) mass and both sorting time and total mass.

RESULTS AND DISCUSSION

1- Sorting Components Percent:

From Fig. (3) through Fig. (6) it is clear that the manual sorting was more acceptable sorting for all components of the input household waste than the mechanical system at all factories under study.

Fig. (3) shows that the manual sorting achieved the highest value of all sorting categories in Abo Greda factory. The manual sorting of household solid wastes components are organic matter (OM) of 89.89 %, paper and carton of 3.00 %, plastic of 3.08 %, leather of 0.88 %, metal of 0.88 %, glass of 0.50 %, clothes of 0.44 % and other of 1.32 %. Meanwhile, the mechanical sorting fulfilled the components percentages of 53.00, 2.10, 2.00, 0.00, 0.51, 0.22, 0.01 and 0.55 % respectively for organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other.

Fig. (4) illustrates that the manual sorting achieved the highest value of all sorting categories in Aga factory. The household solid wastes component sorted manually recorded the percentage of 75.63, 10.52, 5.97, 0.54, 3.54, 1.71, 1.12 and 0.97 % for organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other respectively. Therefore, the corresponding percentages of mechanical sorting components were 40.01, 10.00, 4.70, 0.01, 0.70, 0.30, 0.01 and 0.8 % respectively.

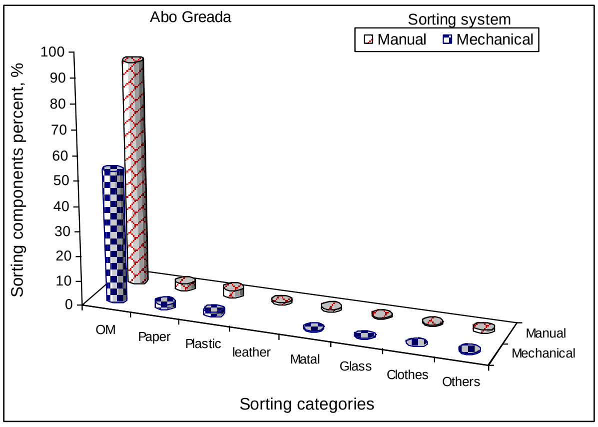

Fig. (3): Sorted household solid waste components at Abo Greada factory.

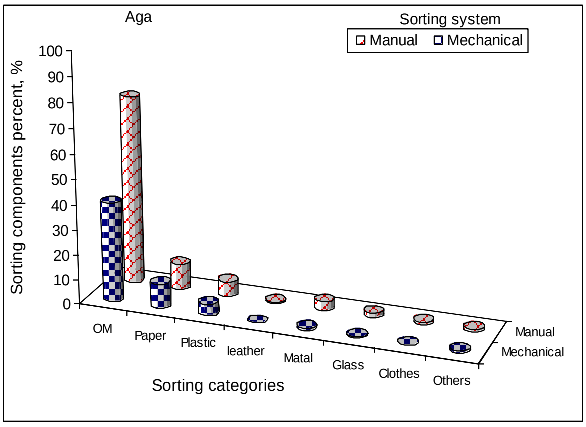

Fig. (4): Sorted household solid waste components at Aga factory.

Fig. (5) clear that the household solid wastes sorting manually achieved the highest value of all sorting categories in Beshla factory. The wastes component sorted manually recorded the percentage of 81.157, 1.43, 7.54, 0.60, 4.93, 1.04, 2.05 and 1.25 % respectively for organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other. Consequently, the corresponding percentages of mechanical sorting are 60.00, 1.20, 6.01, 0.02, 2.60, 0.80, 1.00 and 0.83 % respectively.

From Fig. (6) it can be seen that the manual sorting generated the highest value of all sorting categories in Sandob factory. The manual sorting of household solid wastes components are 72.68, 2.23, 9.75, 1.54, 6.37, 5.07, 0.73 and 1.63 % respectively for organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other. On the other hand, the mechanical sorting components percentages are 38.03, 2.05, 3.50, 0.01, 0.20, 0.21, 0.01 and 0.40 % respectively for organic matter (OM), paper and carton, plastic, leather, metal, glass, clothes and other.

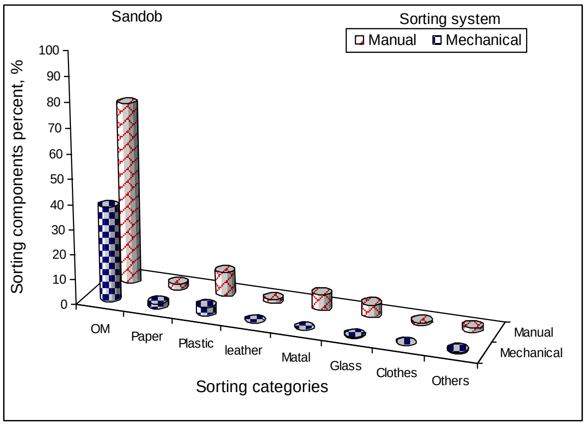

Fig. (5): Sorted household solid waste components at Beshla factory.

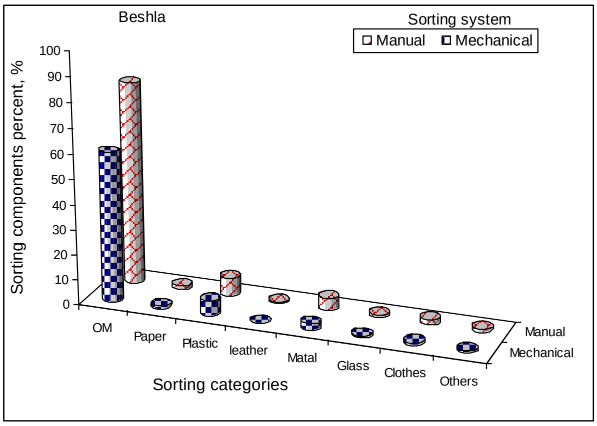

Fig. (6): Sorted household solid waste components at Sandob factory.

The previous results revealed that the manually sorting was accomplished without wastes. On the other hand, the mechanical sorting wastes were about 28 to 56% of the input mass. The organic matter uptake about 21 to 37% of the mechanical sorting wastes (refused). This fecklessness is due to the shortage in labors (Aga factory) and/or number, the difficult to sort the household solid wastes which need many stages to sort, as Beshla factory.

2- Evaluation of Sorting Systems Performance:

Fig. (7) demonstrates that the input amount of household soild wastes were 150, 200, 650 and 250 Mg.day^{-1} for Abo Greda, Aga, Sandob and Bshla factories, respectively. The recycled amounts were 86.79, 111.64, 287.11 and 174.60 Mg.day^{-1} for the previous factories with the same respect. Then wastes amounts were 63.21, 88.36, 362.90 and 75.40 Mg.day^{-1} of input household solid wastes for the factories under study with the previous respect. The results cleared that the percent of the residual and the wastes (refused) in Abo Greada and Aga factories are nearly close due to less sorting steps, while in Beshla factory the wastes are 60.8 % lower than the residual and this is may be due to the manually re-sort of the wastes. On the other side in Sandob factory the wastes 26.4 % higher than the residual this may be due to the machine is old although the using of many steps of sort.

The multiple regression analysis reveal that there is a significant positive relation between Waste (W) and Residual (R) and both sorting time (T) and Input solid wastes (I) as follows:

$$W = 572.68 - 32.07\ T + 0.07\ I \qquad R^2 = 0.9951$$
$$R = -572.68 + 32.07\ T + 0.93\ I \qquad R^2 = 0.9871$$

3- Sorting System Capacity:

Fig. (8) shows that the manual sorting capacity was 0.167 $Mg.labor^{-1}.h^{-1}$. While, the mechanical sorting capacity values were 0.59, 0.78, 0.63 and 0.98 $Mg.labor^{-1}.h^{-1}$ at Abo Greda, Aga, Sandob and Bshla factories, respectively. The difference in sorting capacity values is related to the labors number and their skill.

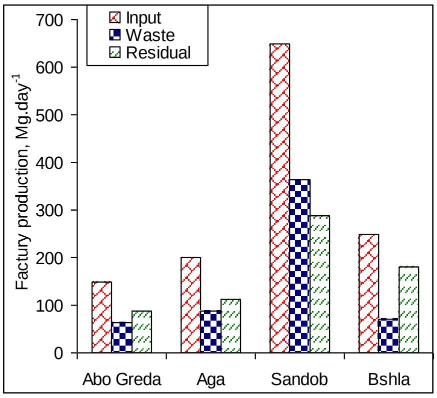

Fig. 7: The factory production, Mg/day.

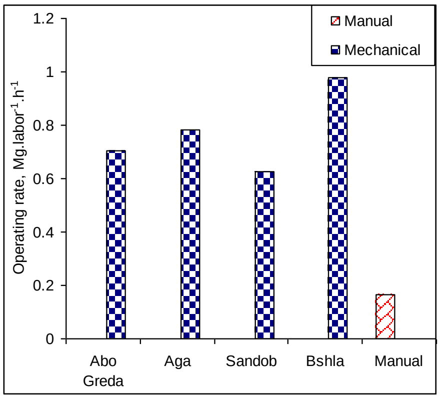

Fig. 8: The operating rate, $Mg.day.labor^{-1}$.

4- Sorting System Efficiency:

Fig. (9) clear that the mechanical sorting efficiency are 58.36, 56.52, 44.37 and 72.44 % for Abo Greda, Aga, Sandob and Bshla factories respectively. These results could be explained that resorting both organic matter and wastes maximized sorting system efficiency at Beshla factory. On the other hand, the higher input amount and depreciation of the operated machines minimized the sorting system efficiency of Sandob factory.

The analysis of variance test indicated that there was high significant difference in system sorting efficiency due to the input amount of household wastes and the sorting system case. LSD test showed that the sorting system of Beshla factory achieved the higher sorting system efficiency among the other treatments.

Suggested sorting system:

The suggestion sorting household solid waste basically depend on the mechanical units to ensures high sorting quality, quantity and low cost. The suggested sorting system consists of 5 main units (Fig. 10) to separate the all household solid waste components "about 9 components". The suggestion sorting system consists of hopper, tilt and horizontal belts, cutting knives, magnetic separator and oscillating separators. The belt properties can be estimated from the following equations:

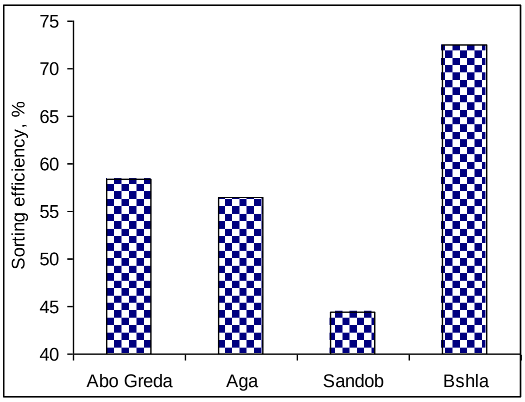

Fig. 9: The sorting efficiency of household solid waste.

1- Belt capacity (B_{cv})

$$B_{cv} = \frac{M_h \times 10}{t \times \rho} \quad , \quad m^3.h^{-1}$$

Where: M_h = Feeding Household solid wastes, Mg
t = Number of daily work, h.
ρ = household density kg.m^{-3}

2- Belt speed (V_b)

$$V_b = \frac{B_{cv}}{900\ (x^2) \times f} \quad , \quad m.s^{-1}$$

Where: x = Loading belt width, m.
f = Coefficient of friction between household and belt

3- Belt width (y)

$$y = \frac{x}{0.9} \quad , \quad m$$

4- Belt movement power (P)

$$P = P_1 + P_2 \quad , \quad kW$$

Where: P_1: Power required to move the belt without load , kW.
P_2: Power required for belt with load , kW

$$P_1 = \frac{F_1\ M_1\ L\ V_b}{1000}$$

Where: F_1: Coefficient of frication between belt and rollers
M_1: Mass of one meter from belt, kg.m^{-1}
L: Distance between the centers of two pulleys, m.
V: Belt speed, m.s^{-1}

Belt may be horizontal then $P_2 = F_2\ B_{cv}\ L$ or tilt then $P_2 = F_2\ B_{cv} \cos\theta\ H$

Where: F_2: Coefficient of frication between material and belt
L : Distance between the centers of two pulleys, m
θ: Tilt angles, degree
H: The belt vertical height, m

Consequently the oscillating amplitude for oscillatory plates can be calculated using the following equation:

$$\text{Amplitude} = \frac{\text{K} \times \text{Centrifugal force}}{\left(\pi \times \frac{\text{Frequency}}{\text{K}_1}\right)^2 \times \text{Effective oscillatory mass}}$$

Where: K and K_1: Constants

The suggested sorting system designed to add some effective units to the present units in the household solid waste factories as follow:

1- The first unit contain the elevator belt with 1.5 m width, 5 m length and 0.4-0.6 $m.s^{-1}$ speed. At 2.5 m from the beginning of the elevator belt and at the 0.20 m height of the belt the magnetic separator is supported. The magnetic separator has a 0.75 width, 1.8 m length, magnetic detector power 320 – 350 Gauss and 1.2 $m.s^{-1}$ speed. The elevator belt acts as a feeding unit to the sieving separator. The sieving separator has a 5 m length, 1.8 m diameter and 25 rpm.

2- The second unit is the specific weight separation unit. It contains four levels of the specific weight separation to separate the 9 categories of the household solid wastes depending on its specific gravity and friction angles. The dimension of the each level is 10 m width and 6 m length. The level trapezoidal in shape the middle with 2 m and the two sides has 4 m width for each. The sides designed by tilt angle.

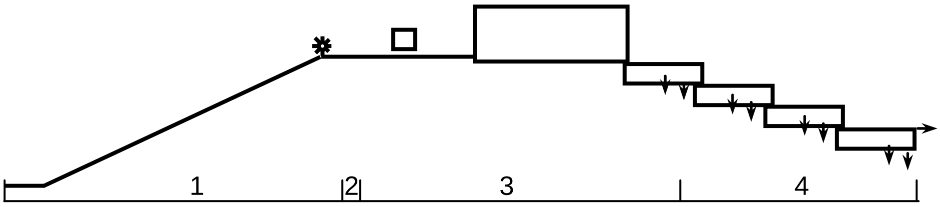

Fig. 10: The diagram of the suggested complete mechanical sorting household solid wastes

CONCLUSIONS

From the results it can be concluded that; the manual sorting is benefit to sort the household solid wastes as quality sorting system (Zero wastes) but opposite in quantity (0.167 $Mg.labor^{-1}.h^{-1}$) that was found by using the mechanical system done in the factories (0.625 – 0.977 $Mg.labor^{-1}.h^{-1}$).

The results explained that the two systems evaluated not enough to sort the all amount of the household wasted produced daily. The complete mechanical suggestion system consists of the adding units to the present factory to improve the waste sort as quality and quantity.

REFERENCES

Arab regulator for education, culture and sciences (2003). Cities engineering and environmental sic. 2nd Ed. Townes. (In Arabic)

Berg, P.E.O. (1993) Källsortering. Teori, metod och implementering. Doctoral thesis. Institutionen för Vattenförsörjnings- och avloppsteknik, Chalmers Tekniska Högskola, Göteborg, Sweden. pp:182. (C.F. Dahlén, L. (2005). To Evaluate Source Sorting Programs in Household Waste Collection

Systems. Luleå University of Technology, Department of Civil and Environmental Engineering, Division of Waste Science & Technology, 71 ISSN: 1402-1757, LTU-LIC, 05/71-ES)

http://www.uae.ii5ii.com (2010)

Kharagpur, I. T. (2007) Machine design. Module 13, Belt drives. Version 2.

Lardinois, I. (1993). Organic Waste. Options for small-scale resource recovery. Urban solid waste series 1, Arnold van de Klundert (eds.), Technology Transfer for Development – Amsterdam, WASTE Consultants - Gouda

Read, A., Harder, M. and Coates, A. (2005) UK best practice in doorstep recycling promotions campaigns (in conference proceedings and oral presentation) Tenth International Waste Management and Landfill Symposium, Sardinia.

Woollam, T. C., Emery, A., Griffiths, A. J. and Williams, K. P. (2003) Key factors in household recycling behaviour in an expanding kerbside recycling scheme. First International Conference on Sustainable Planning and Development, vol.:6, pp:963, Skiathos Island, Greece.

World Health Organization. (1984). Solid Waste Management in South-East Asia. WHO House, New Delhi, India

www.Wekepdia.com (2012)

http://www.dostor.org/society-and-people/variety/11/september/28/56030 (2011).

إقتراح نظام آلى متكامل لفرز المخلفات المنزلية الصلبة

ناهد خيرى إسماعيل*، محمد أحمد شتيوى ونذير محمد البيلى***
*** معهد بحوث الهندسة الزراعية، مركز البحوث الزراعية**
**** كلية الهندسة الزراعية، جامعة الأزهر**

تعد المخلفات المنزلية الصلبة من أهم وأخطر أنواع المخلفات التى تواجه الجنس البشرى خاصة لتراكمها. وبالرغم من أن هذه المخلفات سلاح ذو حدين الأول خطرها على كل عناصر البيئة "التربة – الماء – الهواء" وما يؤدى ذلك من إنتشار للأمراض والأوبئة. أما الثانى أنه لو أحسن إعادة تدوير هذه المخلفات لكانت مصدر هام للدخل القومى. ومن أهم العمليات التى يجب أن تتم لجعل مثل هذه المخلفات مصدر هام من مصادر الدخل عملية الفرز لفصل كل مكون على حده. لذا يهدف هذا البحث إلى تقييم نظم الفرز المتبعة وإعادة تقييمها مع إقتراح نظام فرز ميكانيكى يعتمد على الأساليب والنظريات العلمية لتقليل كمية المخلفات التى لا يتم إعادة تدويرها (مرفوضات) وبالتالى رفع جودة وعائد هذه المخلفات. ويشتمل البحث على تقييم كفاءة أداء نظام الفرز المتبع فى أربع مصانع لتدوير المخلفات المنزلية الصلبة وتحويلها إلى سماد عضوى بمحافظتى الدقهلية ودمياط مقارنة بكمية كل نوع من مكونات المخلفات المنزلية الصلبة عند الفرز اليدوى الكامل وإقتراح نظام آلى للفرز بديلاً عن النظام اليدوى المتبع بالمصانع وذلك بإضافة بعض الوحدات إلى المصانع المقامة بالفعل. ونتج من الدراسة أن الفرز اليدوى أفضل فى جودة الفرز (لا يوجد مرفوضات) مقارنة بالفرز الميكانيكى المتبع ويقل فى الإنتاجية (0.167 ميجاجرام.ساعة/عامل) فى مصانع الفرز فى حين أن إنتاجية المصانع أعلى (تتراوح من 0.625 – 0.977 ميجاجرام.ساعة/عامل). وهذا يعنى أن نظامى الفرز واليجوى غير كافيين لخفض نسبة المرفوضات مع رفع كفاءة الفرز. فى حين نتج من الدراسة من إعادة تكرار عمليات الفرز للمادة العضوية والمرفوضات أدى إلى إنخفاض كميات المرفوضات فى مصنع بشلا إلى نسبة 27.56%. لذا كان من المحتم إقتراح نموذج آلى لوحدة الفرز تعتمد فى عملها على الأسس العلمية لنظم الفصل الآلى على أن تكون ذات مراحل فرز متعدده.ص

قام بتحكيم البحث

أ.د / زكريا ابراهيم اسماعيل	**كلية الزراعة – جامعة المنصورة**
أ.د / سمير احمد طايل	**كلية الهندسه الزراعية – جامعة الازهر**