International Journal of Agricultural Technology 2014 Vol. 10(6):1465-1480
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Application of Crude Palm Oil Liquid Sludge Sewage on Maize (*Zea Mays* L) as Re-Cycle Possibility to Fertilizer

Basri, H. J.[1*], Rosneti, H. [2] and Agusnimar.[3]

[1]Islamic University of Riau Indonesia. Department of Agro-technologyJl. KaharuddinNasution no. 113 Pekanbaru Indonesia 28284; [2]KuatanSingingiRegency, Agriculture Service, TalukKuantan, Riau, Indonesia. ; [3]Islamic University of Riau Indonesia Jl. Kaharuddin Nasution no. 113 Pekanbaru, Indonesia 28284.

Basri, H. J., Rosneti, H. and Agusnimar. (2014). Application of crude palm oil liquid sludge sewage on maize (*Zea mays* L) as re-cycle possibility to fertilizer. International Journal of Agricultural Technology 10(6):1465-1480.

Abstract Many kind results of crude palm oil are very important for foodsand other food substitution materials. The fresh fruits of oil palm has been processing into cooking oil, and about 30 % of row materials appear into liquid or solid sludge sewage. Crude palm oil liquid or solid sludge sewage when processed with suitable process and true management, that the waste becoming fertilizers and possible use to agriculture purpose. Beside, that the negative image of crud palm oils sewage as material or toxic materialsthere could be solved. Crude palm oil liquid sludge sewage was treated to maize with 400 cc/plant could be increased mean relative growth rates, net assimilation rate, leaf area and dry weight of seed. There are indicated that 400cc/plant treated to maize significantly increase the average of mean relative growth rates into 0.32 g.day^{-1}. Net assimilation rates increase from 13.5 mg.m^{-2}.day^{-1} into 34.5 mg.m^{-2}.day^{-1}, leaf are at 50 days after planting increase from 1419 cm^{-2} into 2458 cm^{-2} and dry weight of seed from 38 g per plant into 43 g per plant. Crude palm oil liquid sludge waste chemical analysis indicated that, there are no exceed threshold content of dangerous metals and biology effects. Cadmium (Cd) content as heavy metal is lower than threshold of human healthy tolerance. Therefore, it has no syndrome effect to human health. Biological oxygen demands and chemical oxygen demands as indicators for micro-organism activities, there are under the threshold of human healthy tolerance. Our experiment indicated that the crude palm oil liquid sludge sewage could be used as substitution fertilizer for agriculture use.

Keywords: Crude-palm-oil, fertilizer, liquid-sludge, maize, pollutant, waste

Introduction

Production of cooking oil using fresh fruit of palm oil as row materials has increasingly every year since 2000 in until present in the Riau province Indonesia. The statistical data indicates that in a year 2000 is 7.00 million ton of cooking oil production, and 12.38 million ton in 2004, 19.54 million ton in2008 and 20.00 million ton in 2012 (Badan Biro Statistik, 2012).

[*]**Corresponding author:** Basri, H. J.:**E-mail** hbjumin@gmail.com or hb_jumin@yahoo.com

The preliminary experiment investigation mentioned that, traditionally, thefarmer has beenusing the crude palm oil (CPO) sewage as substitution of fertilizer in small people plantation On the other hand, crude palm oil sewage seen as a problem requiring treatment and disposal. Most conventional sewage treatment options are based on approaches to Indonesian and Asian contries' problems, which has usually meant a reduction in biodegradable organic material and suspended solids, plus perhaps some nutrients (nitrogen and phosphorous). Treatment has involved the 'removal' of these pollutants, but removal is usually conversion to another product, usually sludge. The disposal of sewage sludge is a major consideration in many locations, and it is often seen as an offensive product which is either dumped or burned.

In Indonesia we have no especially regulation concerning application of the waste to agriculture use. However, in European Union there have policies to enhance sludge use in agriculture (Marmo, 2000).Some of the industrial of cooking oil palm conducted integrated waste management using life cycle analysis attempts to offer the most benign options for waste management.

Theavailability ofcrude palm oil is very important as row material, it will be used to increase production of cooking oil. During the fresh fruits of oil palm are processing into cooking oil, about 30 % of materials appear into waste as liquid or solid sludgecrude palm oil liquid sludge waste, and its contributed to environment pollutants. However, after processed with suitable processing and true management that it waste becoming valuable goods as fertilizers. Expanding this research will be conducted to other plants of vegetables. In the future experimentswill be conducted to evaluate the food safety analysis for which fertilized product by crude palm oil liquid sludge waste of oil palm factory.

The objective of the research is to evaluate re-cycle possibility of sludge waste in the Riau oil palm factories there have potential to apply use as a fertilizer for agriculture purposes.

Material and Methods

Research Place and Experiment in Field: This research has been conducted in Palm Oil Plantation Area (part of forest) at Riau province, Indonesia.This province is located in the center of Sumatra Island along the strait of Malacca.This studies were conducted in the cooking oil factory in PT Perkebunan Tri BaktiSarimas located in the KuantanSingingi Prefecture Riau Province. Crude palm oil (CPO) liquid sludge waste was taken out from waste liquid sludge in factory or the gutter of factory disposal (Figure 1).

The treatments of CPO liquid sludge waste (Figure 8) were applied to maize with doses of 0 cc/per (control), 200 cc, 300 cc, 400 cc and 500 cc per plant. Seeds of maize were planted to 10 kg polybag and repeated 10 polybags per treatment.Plants were maintained under about 12 hour photoperiod and natural light intensity, and plants were pouring with enough water (field capacity) if no rain, and no other fertilizers were applied to whole plants.

Relative Mean Growth Rates (RGR): A mean relative growth rate (MRGR) can be calculated by sampling plant size at two points in time.The equation for calculating the MRGR (South, 1995) is written as:

$$\mathbf{MRGR} = \frac{\ln W2 - \ln W1}{t2 - t1}$$

where ***W1*** and ***W2*** are the dry biomass of corn at the beginning (***t1***) and end (***t2***) of the sampling period, and **ln** is the natural logarithm. This is the most common formula used when comparing relative differences between CPO waste treatments

Net Assimilation Rates (NAR): A useful measure of the photosynthetic efficiency of plants is 'net assimilation rate' (*E*) as the rate of increase of dry weight (*W*) per unit of leaf area (*L*) was counted byGregory[1]methods (Vernon and Allison, 1963).It isnet assimilation rate of corn (***E***) definedas the rate of increase of dry weight of maize(***W***) per unit of leaf area of corn (***L***) (Vernon and Allison, 1963); that is:

$$E = \frac{1}{L}\frac{dW}{dt} \qquad (1)$$

In measuring ***W*** the plant is destroyed to calculated dry weight, so changes in ***W*** determined by successive sampling from a population of corn, involving sampling errors. In practice samples are commonly taken at intervals of 1week for measuring ***W*** and ***L***beginning from 3 weeks after planting during vegetative growth. The paired ***W*** and ***L*** sample means may then be used to calculate E_M, an estimate of the mean *E* for each time-interval ($t_2 – t_1$), usually as proposed by Gregory[2] (Vernon and Allison, 1963).

$$E_M = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{} \qquad (2)$$

$(T_2\text{-}T_1)\ (L_2\text{-}L_1)$

Leaf are: The area of the collected leaves measured on a sub-sample using a leaf area meter and image analysis software. Leaf are was measured a twist times namely on 35 days and 50 days after planting. The all data collected will analyze by statistical and presented with tables or graphic or histogram.

Chemical contents of CPO liquid sludge waste wasanalyzed with appropriate procedures atLaboratory of Agro-technology, Faculty of Agriculture, Islamic University of Riau Indonesia. The chemical oxygen demands (CODs),biological oxygen demands (BODs), pH, fat, ammonia, nitrogen, phosphorus, calcium, and heavy metal (Pb, Cu, Cd and Zn) contents were analyzed at Kimpraswil Riau Province Pekanbaru,

Result and Discussion

Relative growth rate**,**a measurement of the productivity of a plant, defined as the increase in dry mass per unit of plant mass over a specified period of time.MRGRof maize after pouring with CPO liquid sludge waste was shown, and the MRGR of maize was presented on Figure1**.**Crude palm oil liquid sludge sewage was treated to maize with 400 cc/plant could be increased MRGR, NAR, leaf area and dry weight of seed. There are indicated that 400 cc / plant treated to maize significantly increase the average of mean relative growth rates into 0.32 $g.day^{-1}$(Table 2). Net assimilation rates increase from 13.5 $mg.m^{-2}.day^{-1}$ into 34.5 $mg.m^{-2}.day^{-1}$ (Figure 2 and Table 3), leaf are at 50 days after planting increase from 1419 cm^{-2} into 2458 cm^{-2} (Figure 4) and dry weight of seed from 38 g per plant into 43 g per plant and there estimated the maize production per hectare until 5.00 ton/hectare (Figure 5). The relative growth rate of maize have shown rapid during early 2 weeks after planting and gradually decrease toward the end of reproductive period. Rapidly growing trees, either during the first few weeks after germination or during the first few months after transplanting often grown according to the variable interest law (South, 1995).

The amount of growth made in a unit of time is a percentage of the size of the maize at the beginning of the period and this percentage changes as the plant increases in size often the percentage declines as size increases. The maize seedling (2 weeks age) show a higher MRGR on the all treatment on CPO liquid sludge waste. Some treatments have a tinyincrease dry weight and there are difficult to make different between to other treatments of CPO sludge waste. However if compared to MRGR of CPO treatments to the no CPO liquid sludge waste treatment (control) is more easily because significantly different. The difficulties to calculate the lower MRGR caused difficult counted the dry weight of biomass. There are meaning a higher MRGR is easily to calculated then the lower MRGR, because there are indicated many problem to apply in small scale.The general belief that a seedling with a higher MRGR is inherently more efficient than one with a lower MRGR has obscured understanding and has caused some confusion. In addition, the general acceptance of the MRGR technique as an appropriate method to remove size-related growth differences has likely diverted attention away from the search for better methods of growth analysis (South, 1995).

For this CPO liquid sludge waste treatment case that maizeseedlings grow according to the variable interest growth law. Most maizeduring their first week of growth show an ontogenetic drift in MRGR as their size increases. In fact, many maize plants exhibit a declining mean relative growth rates over time. In such CPO liquid sludge waste treatments cases, neither the instantaneous relative growth ratesnor the mean relative growth rates are independent of size. In most of these cases, seedlings have been fertilized at an exponentially increasing rate. Some of traditional farmers in Sumatera were applied the CPO sludge as substitution of fertilizers to woody plants. The preliminary observation there were shown the positive effect of CPO liquid sludge waste to its MRGR (Figure 1) and dry seed weight (Figure 4).

The NAR of maize, or unit rate of plant the mean rate of increase in total dry weight per unit area measured over period one week, represent the excess of the mean rate of photosynthesis of the leaves over the mean rate respiration of the whole plant, both expressed per unit leaf area. The NAR based on the increase in plant biomass weight and leaf area a fixed time of maize in all treatments, andit is positive correlation with mean MRGR (Table 2, 3).Dose of 400 CC of CPO liquid sludge waste treatment, had greater NAR than the control (0 cc treatment) solely because they had a greater rate of photosynthesis of the leaves. Differences in NARbetween treatments and control are commonly assumed to reflect changes in the rate of photosynthesis, and this is justifiable for maize that are growing rapidly in dry weigh, when the rate of photosynthesis of the leaves must greatly exceed respiration of the whole plant.

Studies on field crop showed that the NAR differed between doses treatments and control of maize grown in similar environment condition, and this was confirmed when the same species were grown in controlled CPO liquid sludge waste.NAR is a value that relates plantsproductivity to plant size. NAR is obtained by dividing the rate of increase in dry weight by leaf size (leaf area) (Fu. *et al*. 2012). NAR of a whole plant increased with decreasing source/sink ratio, but this can be accounted for by the changes in light interception per unit leaf area, without taking the source–sink relationship into consideration. It was concluded that the altered source/sink ratio did not change leaf photosynthetic capacity and the sink-limitation hypothesis cannot be applied to either cultivar under the conditions of the present study (Matsuda *et al*. 2011).

Based on chemical analysis toCPO liquid sludge waste factory, mentioned that its materialhas no exceed threshold content of dangerous metals and biology effects.For example the content of cadmium (Cd) as a heavy metal and dangerous compound to human health is lower than threshold of human healthytolerance. Therefore, it has no syndrome effect to human body. After processing of the CPO waste in the factory and it throw to reservoir (Figure 6, 7 and 8).In the CPO sludge waste bacteria present in liquid sludge must have BODs to do their part in breaking down the CPO sewage. Waste waters and hence sewage sludge's contain a wide variety of pathogens, which can be infectious for different species of animals and plants as well as for humans (Bohm, 2000) Therefore hygienic principles must be followed in collection, transport, processing, storage and distribution of such materials. Pathogens may survive for a remarkable period of time in sludge's and the environment (Bohm, 2000).

Bacteria and other small organisms in water consume organic matter in sewage of CPO sludge, turning it into new bacterial cells, carbon dioxide, and other by-products. The bacteria normally present in water must have oxygen to do their part in breaking down the sewage. In the 1920s, scientists observed that these natural processes could be contained and accelerated in systems to remove organic material from wastewater. With the addition of oxygen to wastewater, masses of microorganisms grew and rapidly metabolized organic pollutants (United States Environmental Protection Agency, 2004).

Remain chemical product in CPO liquid sludge waste can be used to create changes in pollutants that increase the removal of these new forms by physical and physiological processes. Simple chemicals such as Pb, Cu, Cad and Zn (Table 1), and may be fat, ammonia can be added to wastewater to cause certain pollutants, such as other organic compounds, to bunch together into large, heavier masses which can be removed faster through physical processes. (United States Environmental Protection Agency, 2004), mentioned that over the past 30 years, the chemical industry has developed synthetic inert chemicals know as polymers to further improve the physical separation step in wastewater treatment. Polymers are often used at the later stages of treatment to improve the settling of excess microbiological growth or bio-solids.

The high content of organic materials, of nitrogen and phosphorous and calcium suggest their use as soil conditioner and fertilizer in agriculture. Some wastes contain chemicals capable of suppressing microbiological growth or activity. Potential sources include industrial wastes, antibiotics in pharmaceutical or medical wastes, sanitizers in food processing or commercial cleaning facilities, chlorination disinfection used following conventional sewage treatment, and odor-control formulations used in sanitary waste holding tanks in passenger vehicles or portable toilets. Suppression of the microbial community oxidizing the waste will lower the test result (Hammer, 1975).

Table 1. Result of measurement chemical contents of several parameter of PO liquid sludge waste in the PT Tri BaktiSarimas, KuantanSingingi.

No	Parameter	Unit	Threshold	Result
1	BODs	$mg.l^{-1}$	50	12.5
2	CODs	$mg.l^{-1}$	100	32.3
3	pH	-	6 – 9	5.32
4	Fat	$mg.l^{-1}$	10.0	231*)
5	Nitrogen	$mg.l^{-1}$	1.0	107.7*)
6	Phosphorous	$mg.l^{-1}$	12.	7.0
7	Calcium	$mg.l^{-1}$	500	320
6	Plumbum (Pb)	$mg.l^{-1}$	0.01	0.26
8	Cuprum (Cu)	$mg.l^{-1}$	2.0	0.05
9	Cadmium (Cd)	$mg.l^{-1}$	0.05	0.03
10	Zink (Zn)	$mg.l^{-1}$	5	0.19

**Threshold especially for food eating directly*

Table 2. Mean relative growth rates (MRGR) maize after pouring with CPO sludge waste

Treatments	MRGR 2nd weeks $g.day^{-1}$	MRGR 3rd weeks $g.day^{-1}$	MRGR 4st weeks $g.day^{-1}$	MRGR 5st weeks $g.day^{-1}$
0.0 cc	0.131a	0.110a	0.100a	0.090a
200 cc	0.141ab	0.118a	0.105a	0.100a
300 cc	0.169b	0.141a	0.132a	0.122a
400 cc	0.235c	0.225b	0.214b	0.198b
500 cc	0.200bc	0.175b	0.164c	0.156b

Meanvalue followed by different alphabet/s within column do not differ significantly over one other at P $\leq$0.05 lead by Duncan's Multiple Range Test

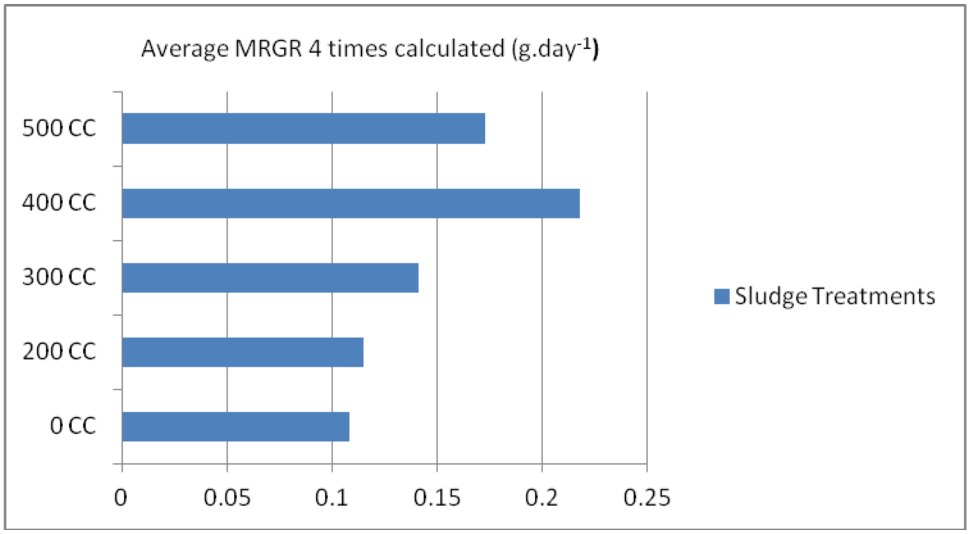

Fig. 1. Relatives growth rate (g.day^{-1})during 1o days of maize after pouring with CPO liquid sludge waste

Table 3. Net Assimilation Rates (NAR) maize after pouring with CPO liquid sludge waste

Treatments	NAR 2nd weeks mg.m^{-2}.day^{-1}	MRGR 3rd weeks mg.m^{-2}.day^{-1}	MRGR 4st weeks mg.m^{-2}.day^{-1}	MRGR 5st weeks mg.m^{-2}.day^{-1}
0.0 cc	16.1a	15.2a	12.3a	10.1a
200 cc	20.3a	18.5b	15.6a	12.3a
300 cc	35.2b	32.6c	30.4b	28.4b
400 cc	40.6c	35.7c	31.3b	30.2b
500 cc	30.4b	28.3c	24.7c	21.8c

Mean value followed by different alphabet/s within column do not differ significantly over one other at $P \leq 0.05$ lead by Duncan's Multiple Range Test

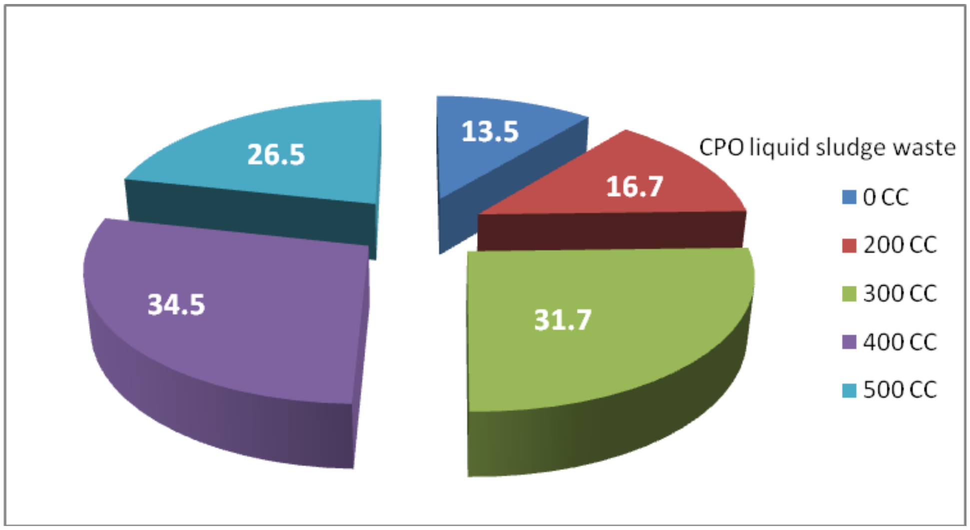

Fig. 2. Average NAR (mg.m^{-2}.day^{-1}) maize after pouring with CPO liquid sludge waste

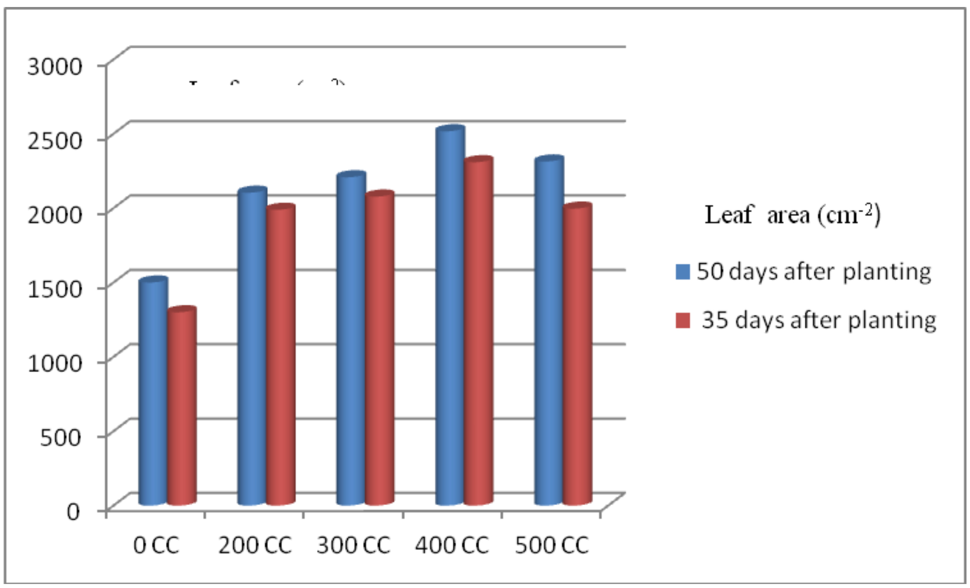

Fig. 3. Leaf area of maize on 35 days and 50 days after planting pouring with CPO liquid sludge waste

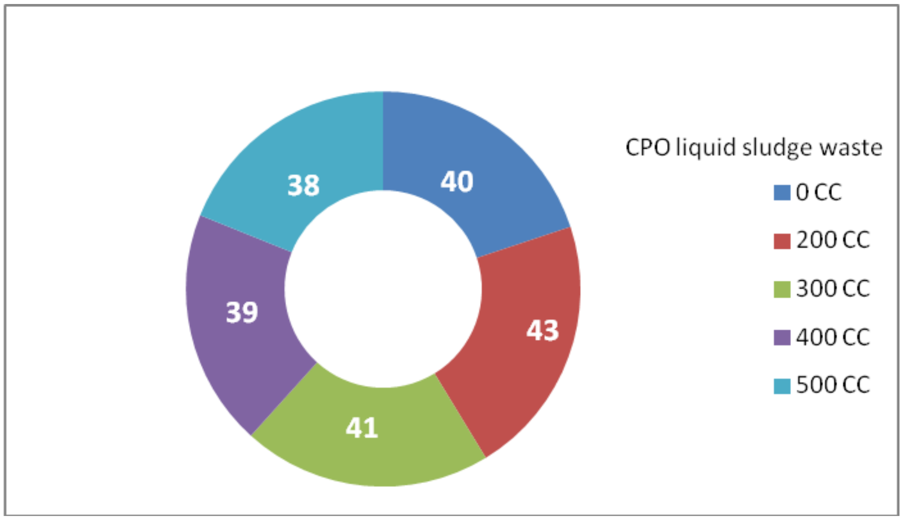

Fig. 4.Dry weight of seed maize(g) of stem of an ear of maize after pouringwith CPO liquid sludge waste

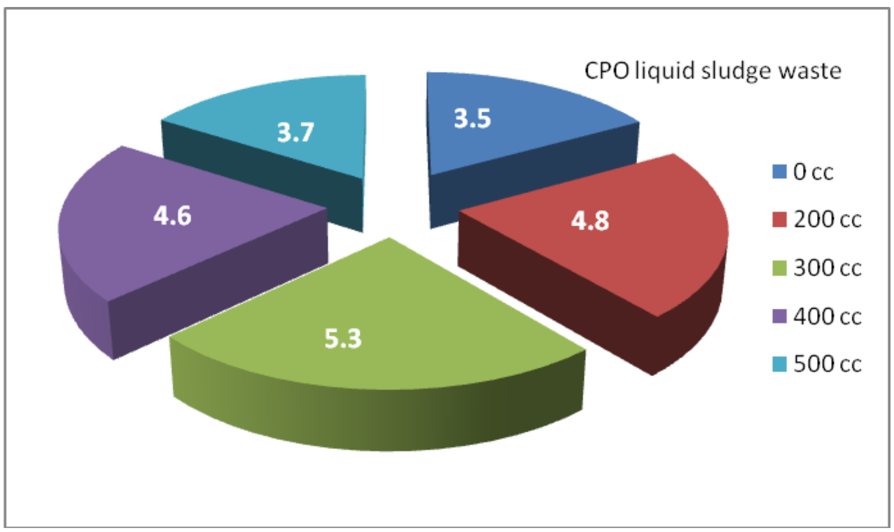

Fig. 5. Rate of production (*estimate*) (ton /ha) of maize after pouring with CPO liquid sludge waste

Fig. 6. Waste of CPO in pipe was flowed to sedimentation reservoirthrow to gutter.

Fig. 7. CPO liquid reservoir was settle became the solid sludge. End of reservoir its waste was settle during 30 days, than it possible to use as fertilizers

Fig. 8. Four kinds of CPO liquid sludge waste taken from reservoirs and its waste will analysis to find chemical and organic compounds

The fresh cluster of fruits are processing into cooking oil and other products. About 30 % of materials appear into waste as liquid or solid sludge. Sewage sludge as an uncalled for product of wastewater treatment poses the challenge to society of disposing of it, but at the same time gives us the opportunity of beneficial use by closing the cycle of nutrients: sludge derived from agricultural activity must return to soil if a sustainable and ecologically sound management of these materials is desirable (Sequi, *et al*. 2000)At present the major ways of disposing of sewage sludge are deposition, landfill and incineration, only part of the sludge are used in agriculture.

Fig. 9.Maize was fertilized with CPO liquid sludge waste56 days after planting

Application of sewage sludge to agricultural land may be beneficial because it can improve the physical, chemical and biological properties of soils which may enhance crop growth (Beck. *et. al*., 1996). To achieve this, sludge application cannot just be a way of disposing of the sludge's but a deliberate application in order to recycle nutrients and to restitute organic matter to soils in order to prevent over-exploitation of agricultural soils in the Community (Marmo, 2000). In addition the use of sludge as a fertilizer would decrease the amounts of chemical fertilizers needed in agriculture (Tidestrom, 1997) and supply micro-nutrients which are not commonly restored in routine agricultural practice. Thus sludge use in agriculture could help save non-renewable materials or energy, a prerequisite to achieve sustainable production (Sequi, *et al*., 2000).

Biological oxygen demands and chemical oxygen demands as indicators for micro-organism activities have also under the threshold of human healthy tolerance. Unfortunately its pH material lies in normal status, so that its liquid sludge is compatible for using as fertilizers in agriculture sector. Carbon, nitrogen, and phosphorus are essential to living organisms and are the chief nutrients present in natural water. In the factory of cooking oil of PT Perkebunan Tri BaktiSarimas, the biochemical oxygen demand is a chemical procedure for determining dissolved oxygen inthe sludge of waste of oil palm needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.After 30 days in the sedimentation the sludge of CPO is possible application to maize and other annual plants (Figure 9) . Event in Indonesia until now no especially domestic waste product law regulate to apply to food plants. However, based on the chemical analyses in laboratory the CPO sludge have no indication content of dangerous chemical for human health (Table1).

In Germanythe fertilizer effects of sludge have to be taken into account according to the rules of the German Fertilizer Act and its respective ordinances when sewage sludge is tobe used in agriculture (Leschber 1992). It is prohibited to use sludge in fruit and vegetable cultivation, on grassland, in nature conservation areas, in forests and near water catchments/wells respectively in water protection areas (Erhardtand Prüeß, 2001). The German regulation comprises limits for AOX (the so-called 'sum of halogenated organic compounds'), polychlorinated biphenylsand polychlorinated dibenzo-p-dioxins and–furans. Sauerbeck and Leschber (1992) report, that the German Ministry of the Environment set these limit values as a purely precautionary measure, they were not based on scientific evidence of immanent toxicological implications. Instead the limit values were based on the current concentrations of the respective compounds in German sewage sludge. Concentrations of AOX in sludge do not really give information about the absence or presence of hazardous substances, this could mean a measure of careful soil protection to prevent the input of high amounts of anthropogenic compounds into soil, some of which may be persistent pollutants (Leschber, 1992).

It is not a precise quantitative test, although it is widely used as an indication of the organic quality of the sludge (Clair *et. al*., (2003)). The test relies upon a microbial ecosystem with enzymes capable of oxidizing the available organic material. Some waste waters, such as those from biological secondary sewage treatment, will already contain a large population of microorganisms acclimated to the water being tested. An appreciable portion of the waste may be utilized during the holding period prior to commencement of the test procedure. On the other hand, organic wastes from industrial CPO sources may require specialized enzymes. Microbial populations from standard seed sources may take some time to produce those enzymes. A specialized seed culture may be appropriate to reflect conditions of an evolved ecosystem in the receiving waters (Hammer, 1975). A standard of 20 ppm BOD as the maximum concentration permitted in sewage works discharging to rivers, provided that there was at least an 8:1 dilution available at dry weather flow.

Some wastes contain chemicals capable of suppressing microbiological growth or activity. Potential sources include industrial wastes, antibiotics in pharmaceutical or medical wastes, sanitizers in food processing or commercial cleaning facilities, chlorination disinfection used following conventional sewage treatment, and odor-control formulations used in sanitary waste holding tanks in passenger vehicles or portable toilets. Suppression of the microbial community oxidizing the waste will lower the test result (Clair *et al*. 2003).

The chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water or liquid material. In this case COD test carried out in the waste sludge of the oil palm. In general, most applications of COD determine the amount of organicpollutants found in surface water (e.g. lakes and rivers, waste water of industrial), making COD a useful measure of water quality, which indicates the mass of oxygen consumed per liter of solution (Clair *et al*. 2003).

Before, peoples in Riau Province mind thinks that the factory sewage ofCPO is a toxic materials to biological, chemical or environment factors previously is no really. Actually the liquid sewage of CPO factory emerges profit for re-cycle materials to protect environment pollution and it could be conducted to sustainable agriculture use.

Based on the analyses of biological oxygen demands (BODs) and chemical oxygen demands (CODs) as indicators for micro-organism activities have also under the threshold of human healthy tolerance (Tabel 1). Twist assignments CODs and BODs has also affected to *p*H medium. Based our measurement, there are pH material lies in neutral condition, so that there are CPO liquid sludge waste is compatible to use as fertilizers substitution in agriculture sector.

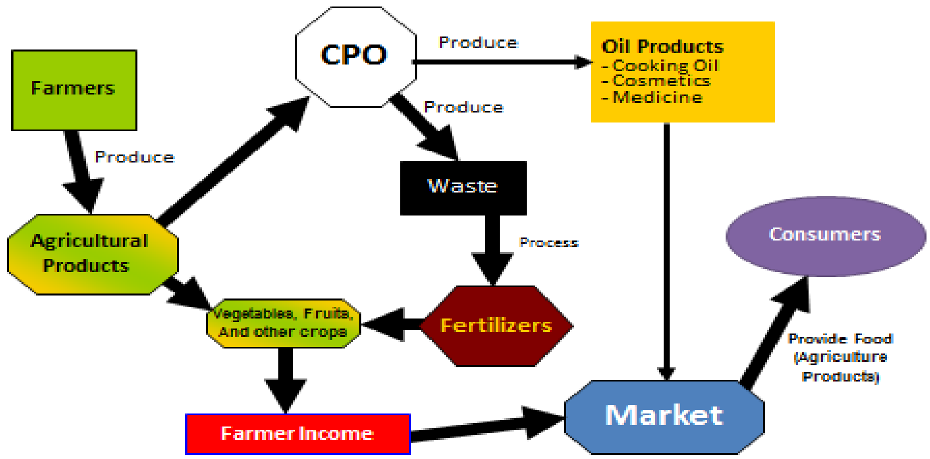

Fig. 10. Circulation system of oil palm will be used as a fertilizer for agriculture use

Conclusion

Finally, the result of maize has also increasingly after pouring with CPO liquidsludge wastes. CPO liquid sludge waste take out from factory treated to maize with suitable doses could be increased MRGR, NAR, leaf area and dry weight of seed. There are indicated that CPO liquid sludge waste is not be a poison to the plant. If CPO liquid sludge waste throw any old way and will occur a pollutants. Nevertheless it is became a fertilizer to plant and it could be used as fertilizers and became economic materials and all at once to save our environment (Figure10).

References

Badan Biro Statistik (2012). Indonesia dalamangka. Badan Pusat Statistik. Jakarta.

Beck, A. J., Johnson, D. L. and Jones, K. C. (1996).The form and bioavailability of non-ionic organic chemicals in sewage sludge-amended agricultural soils. The Science of the Total Environment 185:125-149.

Böhm, R. (2000).Hygienic aspects of sludge reuse.

Clair, N., Sawyer, P., McCarty, L. and Parkin, G. F. (2003).Chemistry for environmental engineering and science. 5th edition. New York: McGraw-Hill.

Erhardt, W. and Prüeß, A. (2001). Organic contaminants in sewage sludge for agriculture use. European Commission. Joint Research Centre Institute for Environment and Sustainability Soil and Waste Unit UMEG Center for Environmental Measurements, Environmental Inventories and Product Safety. Retrieved from www.umeg.de.

Fu, H., Yuan, H. G., Cao, T., Ni, L., Li, W. L. and Zhu, G. (2012). Relationships between relative growth rate and its components across 11 submersed macrophytes. Journal of Freshwater Ecology. pp. 1-10.

Hammer, M. J. (1975). Water and waste-water technology. John Wiley and Sons.

Leschber, R. (1992).Organohalogen compounds in sewage sludges and their determination as cumulative parameters. International Journal of Environmental Analytical Chemistry 44:233-241.

Marmo, L. (2000): Sewage sludge and the Community waste strategy. Workshop on Problems Around Sewage Sludge. Proceedings. European Commissions Joint ResearchCenter, Italy,18-19 November 1999. pp. 17-24.

Matsuda, R., Suzuki, K., Nakano, A., Higashide, T. and Takaichi. (2011). Responses of leaf photosynthesis and plant growth to altered source–sink balance in a Japanese and a Dutch tomato cultivar. Journal of ScientiaHorticulturae 127:520-527.

Tidestrőm, H. (1997). Swedish regulation on the use of sewage sludge in agriculture. Specialty conference on management and fate of toxic organics in sludge appliedto land. Copenhagen.

Sauerbeck, D. R. and Leschber, R. (1992).German Proposals for acceptable contents ofinorganic and organic pollutants in sewage sludge and sludge-amended soils. Luxembourg: Commission of the European Communities.

Sequi, P. F., Tittarelli. and Bendetti, A. (2000). The role of sludge on the reintegration of soilfertility. European Commission Research Centre. pp. 120-132.

South, D. B. (1995). Relative growth rates: a critique. South African Forestry Journal 173:43-48.

United States Environmental Protection Agency (2004). Primer for municipal wastewater treatment systems. United States Environmental Protection Agency, Washington DC.

Vernon, A. J and Allison, J. C. S. (1963). A methods of calculating net assimilation rate. Letter to nature. Nature200. 814 pp.

(Received 14 June 2014, accepted 1 October 2014)