



ADSORPTION OF CARBON DIOXIDE ON ORANGE PEEL AND CARBON SYNTHESIZED FROM ORANGE PEEL

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ABSTRACT

The objective of this research work was to develop a simple and inexpensive process for adsorption of CO₂ using an orange peel powder and carbon made from orange peel powder as an adsorbent. A fixed-bed reactor system was used to study the adsorption capacity as a function of pressure and flow rate. X-ray fluorescence spectroscopy (XRF) was used to determine quantitatively presence of elements. Also the Scanning Electron Microscope (SEM) analysis had been carried out for structure. Results of the experiments showed that the breakthrough adsorption capacity for orange peel powder was 2.604 mmol/g for 5 g and 10 LPH of CO₂. For orange peel carbon the breakthrough adsorption capacity for 14 LPH for 7 g was 5.0843 mmol/g.

Key words: Orange peel, Carbon, Carbon dioxide.

INTRODUCTION

Green house effect caused the global warming, has received increasing attention in recent years. The Intergovernmental Panel on Climate Change (IPCC) predicted that the sea level will rise by 0.09 to 0.88 meters from 1990 to 2100, which will result in 25 percent of the world's population living less than 1.1 meters above sea level. Other probable consequences of global warming include droughts, expanding deserts, heat waves, ecosystem disruption, increasingly severe weather, and loss of agriculture productivity¹.

Researchers have carried out adsorption using high surface area adsorbent, zeolite, alumina or activated carbon in chemical adsorption.² Advanced processes such as CO₂ capture by an ionic liquid etc. have also been suggested³. A high pressure CO₂ separation process in an IGCC plant has been studied by researchers⁴. Molecular sieves were used to remove CO₂ by adsorption in the space station. Due to high cost of adsorbent use of CO₂

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capture from flue gas were imitated⁵. Cryogenic processes can produce liquid CO₂ ready for transportation prior to use or sequestration, but is only worth considering when the CO₂ concentration in flue gas is high⁶. Previously, it has been found that the presence of fine solid particles like activated carbon could enhance the gas-liquid mass transfer for the chemical adsorption technique of CO₂ by K₂CO₃ aqueous solution as the sorbent. Adsorption capacity of the activated carbon could be highly increased by chemical impregnation with the intrinsic nature of activated carbon⁷. Research was focused on to modify specific properties to enhance the effectiveness of activated carbon for developing affinity for different contaminants. Acidic functional groups were introduced onto surface of activated carbon⁸. Research work developed for activated carbon fiber materials and the process of ESA has been reviewed. It was also suggested that electro-thermal swing adsorption could be a good method for CO₂ capture⁹. Activated carbon was synthesized from rice husk and tried to remove 2,4,6-trichlorophenol using response surface methodology¹⁰. From honeycomb-monoliths with different textural properties activated carbon was prepared and chemical activation was done. African palm shells with H₃PO₄, ZnCl₂ and CaCl₂ aqueous solutions of various concentrations. The experimental adsorption isotherms were fitted to Langmuir and Tóth models. From the experiments the maximum adsorption capacity at the highest pressure was (2.627-5.756 mmol·g⁻¹)¹¹. For CO₂ capture porous adsorbents was used. These adsorbents can be used commercially due to their pore size and shape. They can be used over wide range of temperatures and pressures. To improve the affinity towards CO₂ surfaces were modified¹². A new class of crystalline porous materials constructed with different metals and organic bridging legends called metal organic frame work could be used as adsorbents in gas separation. Experimentally it was proved that MOFs was the best adsorbent for CO₂ capture¹³.

In this study, adsorption of CO₂ on the carbon prepared from orange peel and powder of orange peel were studied. The characterizations of orange peel powder and carbon prepared from orange peel such as Scanning Electron Microscope (SEM), elemental analysis, X-ray fluorescence spectroscopy (XRF) and BET surface area has been carried out. The effects of parameters such adsorbent type (orange peel powder and carbon prepared from this powder), the weight of adsorbent (5 g, 6 g and 7 g), and gas flow rate were investigated.

EXPERIMENTAL

Materials and method

Orange peel powder was selected as adsorbent for carbon dioxide. Oranges were collected from local market, and peeled. Peels were washed thoroughly to remove dirt, dried

and powdered. The powder was analyzed for chemical composition, structure and surface area. original powder used for the capture of carbon dioxide. Carbon was made from the powder with the help of 98% H_2SO_4 . The yield of reaction was 66.3% with concentrated H_2SO_4 and orange peel powder to produce carbon. The continuous experiments were carried out for different weight of the material, and different flow rate of gas.

Continuous experiment

Mixture of carbon dioxide (20%) and Argon (80%) was taken for the continuous experiments. Height of the column for continuous experiments was 60 cm and diameter 1 cm with inlet at bottom and outlet at the top of the column. 5 g of original orange peel powder filled into column and height was measured. The empty space filled with glass beads. The mixture of CO_2 and Argon passed through the inlet at the different flow rate i. e. 10, 12 and 14 LPH. Outlet of the column was connected to the CO_2 analyzer. [(CO_2 Analyzer (NUCON MODEL: 2007. Principle: Non Dispersive Infra Red range: (0 to 20%)). With the help of CO_2 analyzer the quantity of CO_2 adsorbed in the material was calculated. Same procedure followed for the 6 and 7 g of original orange peel powder and carbon made from orange peel powder at different flow rate. Fig. 1 shows the schematic representation of experimental setup.

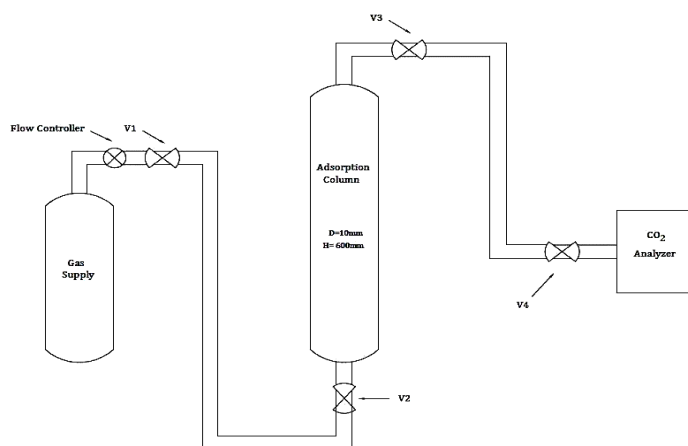


Fig. 1: The schematic representation of continuous experimental setup

RESULTS AND DISCUSSION

Characteristics of the adsorbent

The surface morphological changes of powder and carbon samples were investigated using a Scanning Electron Microscope (SEM). The Fig. 2 and 3 shows the Scanning

Electron Microscopy of orange peel powder and carbon made from powder. Carbon made from powder showed more porous structure than orange peel powder. Orange peel powder showed vertical vein type structure and carbon made from powder showed more porous structure with holes, which gave maximum adsorption capacity than the orange peel powder.

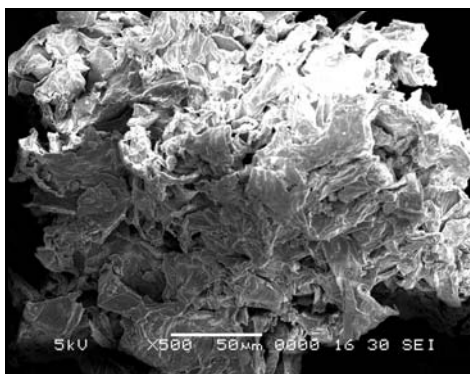


Fig. 2: Scanning electron microscopy of orange peel powder

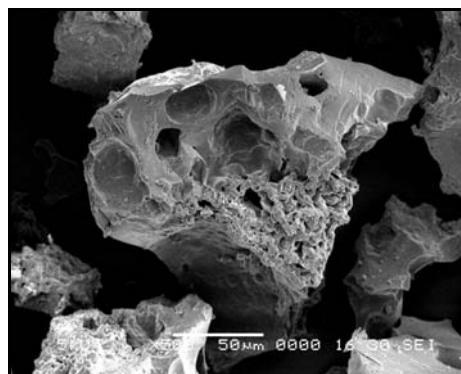


Fig. 3: Scanning electron microscopy of orange peel carbon

Table 1 and 2 represent the elemental analysis of orange peel powder and carbon made from orange peel powder, respectively. Besides that this component is widely used to be manufactured as an adsorbent to adsorb (CO_2) gas. Orange peel contain potassium oxide (K_2O) with 1.72%, calcium oxide (CaO) with 1.31% and others components in the minority. Therefore, with the great amount of carbon component, carbon produced from orange peel and also orange peel itself is one of the potential adsorbent to adsorb CO_2 from gas mixture¹⁴.

Table 1: Elemental analysis from orange peel powder

S. No.	Element	Wt. %
1	Carbon	51.53
2	Oxygen	43.95
3	Potassium	1.72
4	Calcium	1.31
5	Platinum	1.30
6	Magnesium	0.19

Table 2: Elemental analysis of carbon made of orange peel powder

S. No.	Element	Wt. %
1	Carbon	64.26
2	Oxygen	32.49
3	Sulfur	1.55
4	Calcium	1.43
5	Platinum	0.27

The raw material was treated with A. R. grade concentrated H_2SO_4 . The carbonized material was washed with distilled water (8 to 10) times to get it free from acid and then filtrated it by filtration paper and then dried it to get carbon without any moisture. The dried carbon was grounded and sieved to get uniform size. Synthesized carbon was analyzed for elemental analysis by using X-ray fluorescence spectroscopy (XRF). The total 10 elements were detected. The details are reported Table 3 and 4. From the Table 3, it was found that the most containing of elements in orange peel are calcium as a calcium oxide (CaO) (48.54%), potassium as a potassium oxide (K_2O) (37.66%) and silicon as a silicon dioxide or silica (SiO_2) (6.293%). Elements in the carbon, which produced from orange peel as a raw material, was found calcium as a calcium oxide (CaO) (71.51%), silicon as a silicon dioxide or silica (SiO_2) (17.39%) and iron as a (Fe_2O_3) (2.815%), with the great amount of these components in the carbon more than in orange peel, the carbon has more potential as adsorbent than orange peel to adsorb CO_2 .¹⁵

Table 3: XRF analysis for orange peel powder

S. No.	Element	(Wt. %)
1	Silicon	6.293
2	Aluminium	0.5219
3	Potassium	37.66
4	Calcium	48.54
5	Titanium	0.1600
6	Sodium	0.2457
7	Magnesium	1.6093

Cont...

S. No.	Element	(Wt. %)
8	Phosphorus	4.4035
9	Manganese	4.4035
10	Iron	0.5090

Table 4: XRF analysis of carbon made from orange peel powder

S. No.	Element	(Wt. %)
1	Silicon	17.39
2	Aluminium	0.9036
3	Potassium	0.9036
4	Calcium	71.51
5	Titanium	0.7083
6	Sodium	0.6371
7	Magnesium	0.1543
8	Phosphorus	1.943
9	Manganese	0.064
10	Iron	2.815

Tables 6-8 represent the CO₂ breakthrough adsorption capacity and length of mass transfer zone (LMTZ) for 5 g, 6 g and 7 g orange peels powder respectively and Tables 9-11 represent the CO₂ breakthrough adsorption capacity and Length of mass transfer zone (LMTZ) for 5 g, 6 g and 7 g orange peels carbon, respectively and Figs. 4-9 describes the break through characteristics at these concentrations.

Table 5: Orange peel powder (5 g)

S. No.	Gas flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of mass transfer zone)
1	10 LPH	2.604 mmol /g	5.8 cm
2	12 LPH	0.4464 mmol /g	8.2857 cm
3	14 LPH	0.69444 mmol/g	6.214 cm

Table 6: Orange peel powder (6 g)

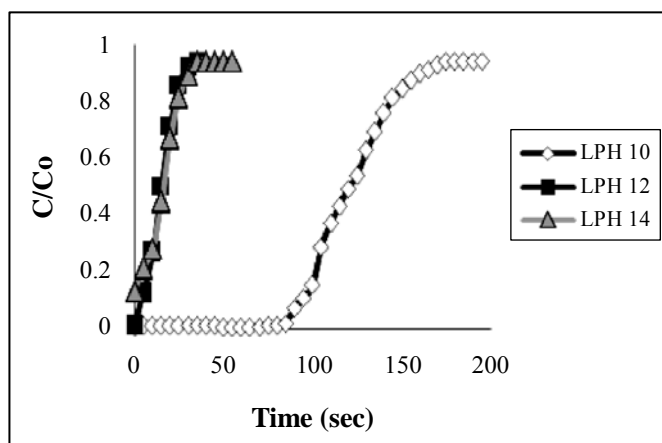
S. No.	Gas flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of mass transfer zone)
1	10 LPH	0.93 mmol/g	6.0714 cm
2	12 LPH	0.868 mmol/g	7.846 cm
3	14 LPH	1.3 mmol/g	5.23 cm

Table 7: Orange peel powder (7 g)

S. No.	Gas flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of mass transfer zone)
1	10 LPH	0.442857 mmol/g	11.375 cm
2	12 LPH	1.5944 mmol/g	6.7826 cm
3	14 LPH	2.108 mmol/g	7.2222 cm

Table 8: Orange peels carbon (5 g)

S. No.	Gas Flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of Mass Transfer Zone)
1	10 LPH	2.48 mmol/g	4.9417 cm
2	12 LPH	2.52977 mmol/g	7.0244 cm
3	14 LPH	2.43055 mmol/g	5.28 cm

**Fig. 4: Adsorption of carbon dioxide on orange peel powder (5 g) for 10, 12 and 14 LPH**

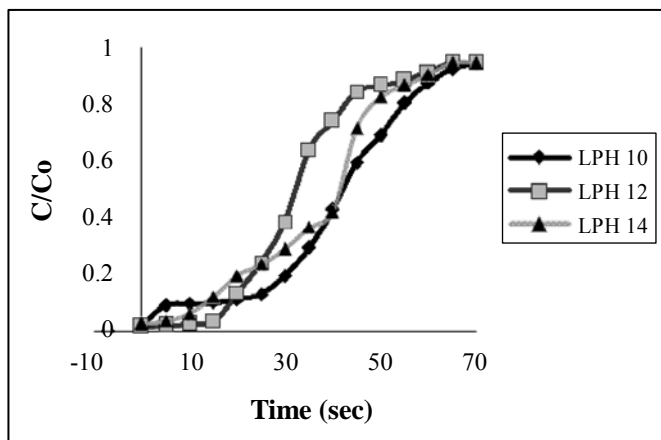


Fig. 5: Adsorption of carbon dioxide on orange peel powder (6 g) for 10, 12 and 14 LPH

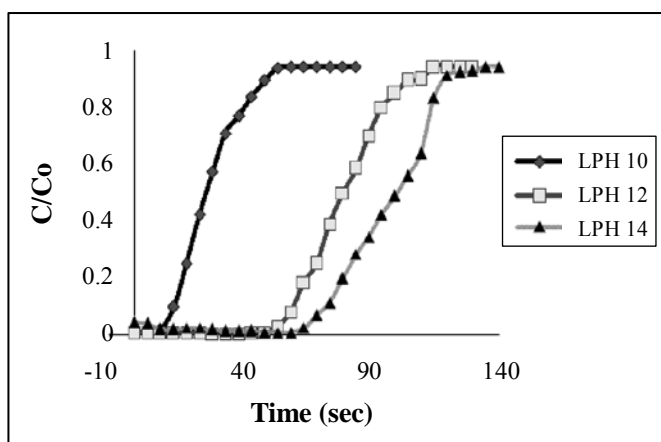


Fig. 6: Adsorption of carbon dioxide on orange peel powder (7 g) for 10, 12 and 14 LPH

Table 9: Orange peels carbon (6 g)

S. No.	Gas flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of Mass Transfer Zone)
1	10 LPH	2.0667 mmol/g	4.5 cm
2	12 LPH	3.844 mmol/g	3.292 cm
3	14 LPH	4.485 mmol/g	3.7674 cm

Table 10: Orange peels carbon (7 g)

S. No.	Gas Flow rate, LPH	CO ₂ capture capacity (Breakthrough adsorption capacity)	LMTZ (Length of Mass Transfer Zone)
1	10 LPH	3.45428 mmol/g	3.52 cm
2	12 LPH	1.7 mmol/g	5.333cm
3	14 LPH	5.0843 mmol/g	5.5873 cm

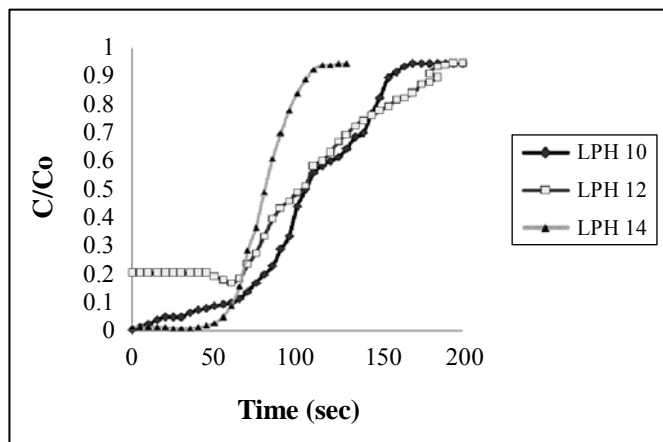


Fig. 7: Adsorption of carbon dioxide on carbon made from orange peel powder (5 g) for 10, 12 and 14 LPH

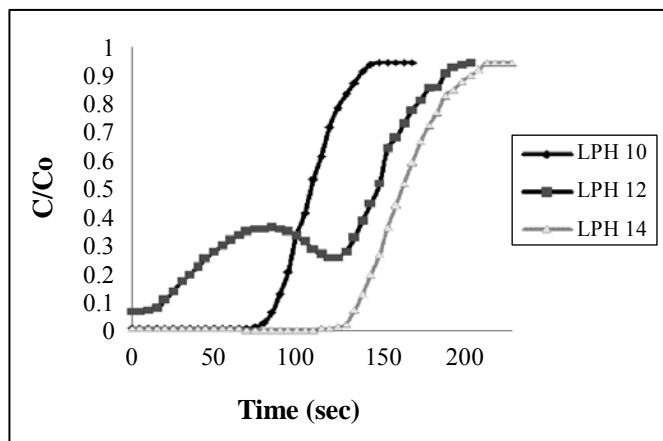


Fig. 8: Adsorption of CO₂ gas on orange peel carbon (6 g) for 10, 12 and 14 LPH

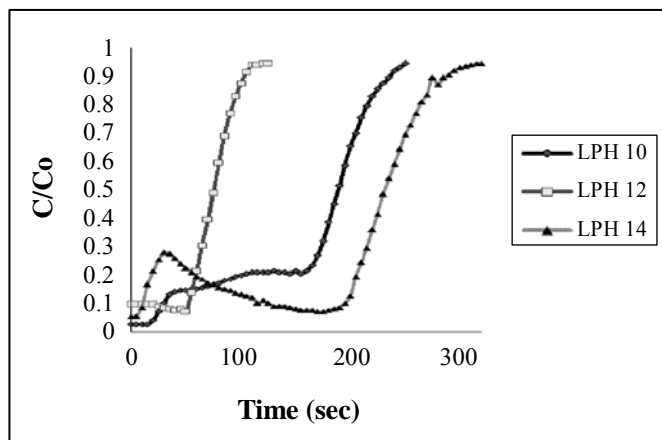


Fig. 9: Adsorption of carbon dioxide on carbon made from orange peel powder (7 g) for 10, 12 and 14 LPH

The maximum breakthrough adsorption capacity 2.604 mmol/g was observed at 10 LPH gas flow rate and at 5 g of orange peel powder. But while increasing the amount of orange peels powder 6 g and 7 g, the maximum breakthrough adsorption capacity was observed 1.3 mmol/g and 2.108 mmol/g at 14 LPH.

Similarly, the maximum break through adsorption capacity 2.52977 mmol/g was observed at 12 LPH gas flow rate at 5 g of orange peel carbon powder. But while increasing the amount of orange peels carbon powder i. e. 6 g and 7 g, the maximum breakthrough adsorption capacity was observed 4.485 mmol/g and 5.0843 mmol/g at 14 LPH.

CONCLUSION

Low cost carbon was synthesized from the orange peels. The utilization of the orange peels is promising adsorbent as it consists of mainly carbon and low in inorganic content, aside from the minimization of the waste problems. Carbon synthesized from orange peel powder was found was a good adsorbent than the orange peel powder. Results showed that, as the amount of adsorbent was increased the breakthrough time considerably decreased.

Also, it was observed that, the decrease in the breakthrough and adsorption times was relatively larger at higher amount levels. Surface area of the carbon synthesized from orange peel was less but in future, it can be increased by different methods to improve adsorption capacity.

REFERENCES

1. C.-H. Yu, C. H. Huang and C.-S. Tan, A Review of CO₂ Capture by Absorption and Adsorption, *Aerosol and Air Quality Research*, **12**, 745-769 (2012).
2. Bates, Eleanor D., Mayton, Rebecca D., Ntai, Ioanna, and Davis, James H., CO₂ Capture by a Task-Specific Ionic Liquid, *J. Am. Chem. Soc.*, **124(6)**, 926-927 (2002).
3. Deppe, Gordon et al., A High Pressure Carbon Dioxide Separation Process in an IGCC Plant, *Proceedings of the Conference on the Future Energy Systems and Technology for CO₂ Abatement*, Antwerp, Belgium, November, 97-106 (2002).
4. M. M. Halmann and M. Steinberg, *Greenhouse Gas Carbon Dioxide Mitigation, Science and Technology*, Lewis Publishers, Boca Raton, FL, (1999) p. 568.
5. K. W. Lee, Clean Fuels from Biomass, *Am. Chem. Soc. Div. Fuel Chem. Prepr.*, **46(1)**, 61-64 (2001).
6. E. Salehi, V. Taghikhani, C. Ghotbi, E. Nemati Lay and A. Shojaei, Theoretical and Experimental Study on the Adsorption and Desorption of Methane by Granular Activated Carbon at 25°C, *J. Nat. Gas Chem.*, **16**, 415-422 (2007).
7. Y. C. Yang, A. Mohd. Kheireddine and W. D. Wan Mohd. Asri, Review of the Modifications of Activated Carbon for Enhancing Contaminant Uptakes from Aqueous Solutions, *Separation Purification Technology*, **52**, 403-415 (2007).
8. Hui An, Bo Feng and Shi Su, CO₂ Capture by Electro Thermal Swing Adsorption with Activated Carbon Fibre Materials, *Int. J. Greenhouse Gas Control*, **5**, 16-25 (2010).
9. I. A. W. Tan, A. L. Ahmad and B. H. Hameed, Preparation of Activated Carbon from Coconut Husk, Optimization Study on Removal of 2,4,6-trichlorophenol using Response Surface Methodology, *J. Hazard. Mater.*, **153**, 709-717 (2008).
10. Diana P. Vargas, Liliana Giraldo and Juan C. Moreno-Piraján, CO₂ Adsorption on Activated Carbon Honeycomb-Monoliths: A Comparison of Langmuir and Tóth Models, *Int. J. Mol. Sci.*, **13**, 8388-8397 (2012).
11. U. M. Baba, K. S. N. Kamarudin and N. Alias, Separation of Carbon Dioxide Using Selected Porous Materials: A Review, *Int. J. Chem. Environ. Engg.*, **1(1)**, 40-46 (2010).
12. Jian-Rong Li a, Yuguang Mab, M. Colin McCarthyb and Julian Sculleya, Carbon Dioxide Capture-Related Gas Adsorption and Separation in Metal-organic Frameworks, *Coordination Chem. Rev.*, **255**, 1791-1823 (2011).

13. S. C. Scholl, H. Kajsziika and A. B. Mersmann, Adsorption and Desorption Kinetics in Activated Carbon, *Gas Sep. Purif.* **7(4)**, 207 (1993).
14. C. Brasqueta, B. Rousseaub, H. Estrade-Szwarcopfb and P. Le Cloireca, Observation of Activated Carbon Fibres with SEM and AFM, Correlation with Adsorption Data in Aqueous Solution, *Carbon*, **38**, 407-422 (2000).
15. Aeslina Abdul Kadir, Alida Abdullah and Lee Kah Wai, Study on Ferum (Fe) and Zinc (Zn) Removal by using Rice Bran at Sungai Pelepah, Kota Tinggi, Joho, *Advances in Environ. Biol.*, **7(12)**, 3580-3586 (2013).

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