REGENERATION AND CHARACTERIZATION OF SPENT BLEACHING CLAY

By

NUR SULIHATIMARSYILA BT. ABD. WAFTI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

March 2006

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

REGENERATION AND CHARACTERIZATION OF SPENT BLEACHING CLAY

By

NUR SULIHATIMARSYILA BT. ABD. WAFTI

March 2006

Chairman: Associate Professor Thomas Choong Shean Yaw, PhD

Faculty: Engineering

The spent bleaching clay (SBC), a solid waste generated from palm oil refinery, may be recycled rather than simply disposed off in landfill. The aim of this study is to investigate the heat regeneration of SBC and to evaluate the performance of the heat-treated SBC on the bleaching of crude oil. The quality of oil is first studied. The quality of the oil extracted from spent bleaching clay from palm oil refinery (SBC-PO) and spent bleaching clay from palm kernel oil refinery (SBC-PKO) much inferior compared to that of crude oil. De-oiling efficiency for both SBC increases as the solid to solvent ratio is decreased.

Two type of SBC are studied such as acid-activated clay (XMP, WAC) and natural clay (AH). Two types of regeneration processes are performed, such as (a) solvent extraction followed by heat treatment and (b) regeneration carried out by direct heat treatment. Heat treatment is conducted in a box furnace at temperatures ranging from 400 to 1000°C. Red color indices of oils are used to determine the regeneration efficiency. Spent bleaching clay produced by direct

heat treatment (HRSBC), yields a higher regeneration efficiency than the deoil-heat-regenerated spent bleaching clay (DHRSBC), produced by solvent extraction and heat treatment. The specific surface area, total pore volume and average pore size of SBC are measured using nitrogen adsorption-desorption method. The proximate analysis is also performed to clarify the mechanism of regeneration process. The data shows that the HRSBC at 500°C possess the highest specific surface area and total pore volume and give better bleaching efficiency than that of HRSBC at 400 and 800°C. All the regenerated SBC samples are mesoporous material.

Adsorption isotherm is useful for determining the efficiency of the HRSBC in removing pigments. The Henry's Law equation is found to be more applicable than the Langmuir and Freundlich isotherms in the adsorption of pigments from degummed palm oil on HRSBC. The adsorptive efficiency of the HRSBC is optimum at regeneration temperature of 500°C.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMULIHAN SEMULA DAN SIFAT TANAH PELUNTUR TERGUNA

Oleh

NUR SULIHATIMARSYILA BT. ABD. WAFTI

Mac 2006

Pengerusi : Profesor Madya Thomas Choong Shean Yaw, PhD

Fakulti : Kejuruteraan

Tanah peluntur terguna (TPT) adalah sisa pepejal terhasil daripada kilang pemprosesan minyak sawit, boleh dikitar semula selain daripada dibuang ke tempat pelupusan. Tujuan penyelidikan ini adalah untuk menyiasat proses pemulihan menggunakan pemanasan haba terhadap TPT serta menilai kecekapan TPT haba-terpulih terhadap proses pelunturan minyak mentah. Kualiti minyak tersimpan dikaji terlebih dahulu. Kualiti minyak yang diekstrak daripada TPT dari kilang minyak sawit dan minyak isirung kelapa sawit adalah lebih rendah berbanding minyak mentah. Kecekapan membuang minyak tersimpan untuk kedua-dua TPT meningkat apabila nisbah pepejal kepada larutan hexane menurun.

Dua jenis TPT telah digunakan iaitu peluntur tanah asid teraktif (WAC, XMP) dan peluntur tanah semulajadi (AH). Dua jenis proses pemulihan telah digunakan iaitu (a) pengekstrakan larutan diikuti dengan pemulihan pemanasan haba dan (b) pemulihan oleh pemanasan haba terus. Pemulihan secara pemanasan telah dijalankan di dalam relau berkotak pada suhu di antara 400 hingga 1000°C. Warna merah minyak sawit mentah dan minyak sawit yang diproses digunakan untuk mengira kecekapan pemulihan. TPT yang

dihasilkan oleh pemanasan haba terus memperolehi kecekapan pemulihan yang lebih tinggi berbanding TPT yang dihasilkan daripada pengekstrakan larutan dan pemanasan haba. Luas permukaan spesifik, jumlah isipadu ruang dan pembahagian saiz ruang dianalisa, diperolehi daripada kaedah penjerapan-nyahpenjerapan nitrogen. Penentuan analisa yang paling hampir ditentukan dengan tujuan untuk menerangkan mekanisma proses pemulihan. Data menunjukkan bahawa TPT dari pemanasan haba terus pada suhu 500°C menghasilkan luas permukaan spesifik dan jumlah isipadu ruang paling tinggi serta memberi kecekapan pelunturan lebih baik daripada TPT terpulih pada suhu 400 dan 800°C. Semua sampel TPT menunjukkan sifat bahan yang mempunyai ruang *meso*.

Isoterma penjerapan berfaedah untuk menentukan kecekapan TPT terpulih dalam menyingkirkan pikmen. Hukum *Henry* didapati lebih sesuai digunakan berbanding isoterma *Langmuir* dan isoterma *Freundlich* dalam penjerapan pikmen daripada minyak sawit yang dinyahgam oleh TPT terpulih haba dari proses pemanasan terus. Kecekapan penjerapan adalah optima pada suhu pemulihan 500°C.

ACKNOWLEDGEMENTS

Alhamdulillah, at last this thesis has finally completed. The author wishes to express her deepest appreciation to her supervisor Dr. Thomas Choong Shean Yaw and co-supervisors Dr. Luqman Chuah Abdullah, Dr. Cheah Kien Yoo and Dr. Siew Wai Lin for their guidance, insightful comments and patient supervision of this work.

The author would like to extend her gratitude to Sci-Pneucon Automation Industrial Sdn. Bhd. for the financial support in completing this research.

To overcome the technical and laboratory difficulties, the author has been advised by two groups of expert: staff and officers from Malaysian Palm Oil Board (MPOB) as well as lecturers and research assistants from Universiti Putra Malaysia (UPM). It is not an exaggeration to state that this work could not have been completed without their counsel and assistance throughout the studies.

The author also owes a special debt of thanks to her fellow colleagues for their helping hand. The author wishes to express her deepest appreciation to beloved husband for his understanding and support during this study. And, lastly, the author is very indebted to her family and friends for their encouragement and sharing time throughout this two years journey.

I certify that an Examination Committee has met on 28th March 2006 to conduct the final examination of Nur Sulihatimarsyila Bt. Abd. Wafti on her Master of Science thesis entitled "Regeneration and Characterization of Spent Bleaching Clay" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Tay Beng Ti, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd. Amran b. Mohd Salleh, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Nor Hafizah bt. Abdullah, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Rosli Mohd. Yunus, PhD
Associate Professor
Faculty of Engineering
Universiti Teknologi Malaysia
(External Examiner)

____

HASANAH MOHD. GHAZALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Thomas Choong Shean Yaw, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Luqman Chuah Abdullah, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Cheah Kien Yoo, PhD
Senior Research Officer
Malaysian Palm Oil Board
(Member)

Siew Wai Lin, PhD
Senior Research Officer
Malaysian Palm Oil Board
(Member)

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that is has not been previously or concurrently submitted for any other degree at UPM or other institutions.

____

NUR SULIHATIMARSYILA BT. ABD. WAFTI

Date: 28 May 2006

TABLE OF CONTENTS

Page

ABSTRACT		ii
ABSTRAK		iv
ACKNOWLEDGEMENTS		vi
APPROVAL		vii
DECLARATION		ix
TABLE OF CONTENTS		x
LIST OF TABLES		xii
LIST OF FIGURES		xii
LIST OF NOTATIONS/SYMBOLS/ABBREVIATIONS		xvii
CHAPTER		
1	INTRODUCTION	1.1
2	LITERATURE REVIEW	
	2.1 Introduction	2.1
	2.2 Refining of Palm Oil	2.1
	2.3 Bleaching Clay	2.4
	2.4 Spent Bleaching Clay	2.7
	2.5 Regeneration Methods of Spent Bleaching Clay	2.9
	2.5.1 Solvent Extraction and Regeneration by Heat and Treatment	2.10
	2.5.2 Regeneration by Direct Heat Treatment	2.12
	2.6 Application of Regenerated Spent Bleaching Clay	2.17
	2.7 Adsorption	2.18
	2.7.1 Adsorption Isotherm	2.19
	2.7.2 Adsorption Isotherm on Removal of Pigments from Oil	2.21
	2.8 Summary	2.22
3	MATERIAL AND METHOD	
	3.1 Introduction	3.1
	3.2 Materials	
	3.2.1 Fresh Bleaching Clay	3.1
	3.2.2 Spent Bleaching Clay	3.2

3.2.3 Crude Oil 3.2
3.2.4 Solvent 3.2
3.3 Methodology
3.3.1 Solvent Extraction and Regeneration by Heat Treatment 3.3
3.3.2 Regeneration by Heat Treatment 3.4
3.4 Characterization of Bleaching Clay

3.4.1 Determination of Weight Loss
3.4
3.4.2 Determination of Proximate Analysis
3.5
3.4.3 Determination of Physical Properties of Bleaching Clay 3.5
3.5 Performance Test
3.5.1 Laboratory Physical Refining of Oil for Bleachability Test
3.6
3.5.2 Calculation of Regeneration Efficiency
3.9
3.6 Analysis of Oil
3.6.1 Determination of Color
3.9
3.6.2 Determination of Carotene Content
3.10
3.6.3 Determination of Specific Extinction in Ultraviolet Light
3.10
3.6.4 Determination of Chlorophyll Concentration
3.10
3.6.5 Determination of Deterioration of Bleachability Index
3.11
3.6.6 Determination of Iodine Value
3.11
3.6.7 Determination of Free Fatty Acid
3.11
3.7 Adsorption Isotherm
3.12

4 RESULT AND DISCUSSION
4.1 Introduction 4.1
4.2 Solvent Extraction and Regeneration by Heat Treatment
4.2.1 Quality of Oil Extracted from Spent Bleaching Clay
4.1
4.2.2 Effect of Spent Bleaching Clay to Solvent Ratio on Deoiling Efficiency 4.5
4.2.3 Effect of Regeneration Temperature 4.8
4.2.4 Relationship between Physical Properties and
4.9
Regeneration Efficiency
4.3 Regeneration by Direct Heat Treatment
4.12
4.3.1 Effect of Regeneration Temperature
4.12

4.3.2 Relationship between Physical Properties and Regeneration Efficiency 4.16
4.4 Characterization of Bleaching Clay 4.19
4.4.1 Effect of Regeneration Temperature 4.19
4.4.2 Effect of Different Type of Regenerated Bleaching Clay 4.27
4.4.3 Effect of Different of Regeneration Method 4.31
4.4.4 Proximate Analysis and Weight Loss 4.33
4.5 Adsorption Isotherm 4.38
4.5.1 The Langmuir Isotherm 4.38
4.5.2 The Freundlich Isotherm 4.40
4.5.3 The Henry's Law 4.43

5 CONCLUSION AND RECOMMENDATION 5.1

BIBLIOGRAPHIES R.1
APPENDICES A.1
BIODATA OF THE AUTHOR B.1

LIST OF TABLES

Table		Page
2.1	Summary of studies on regeneration of spent bleaching clay	2.14
2.2	A summary of application of regenerated spent bleaching clay	2.17
3.1	Commercial fresh bleaching clays	3.2
3.2	Spent bleaching clay samples	3.2
3.3	The methods and corresponding relative pressure range in determination of the porosity parameters	3.6
4.1	Characteristics of crude oil and oil extracted from SBC	4.2
4.2	Fatty acid compositions of crude oil and oil extracted from SBC	4.4
4.3	The physical properties of fresh bleaching clay	4.9
4.4	Physical properties of DHRSBC-PO and DHRSBC-PKO	4.10
4.5	The colour of CPO after bleaching using the DHRSBC	4.11
4.6	The colour of CPO after bleaching using the HRSBC	4.15
4.7	Physical properties of HRSBC-PO and HRSBC-PKO	4.16
4.8	The physical properties of fresh and HRSBC of acid-activated and natural bleaching clay	4.17
4.9	The proximate analysis of spent bleaching clay and deoiled bleaching clay	4.33
4.10	Effects of regeneration temperature on weight loss and proximate analysis	4.34
4.11	Effects of regeneration temperature on weight loss and proximate analysis of WAC and AH HRSBC	4.37
4.12	Characteristic of crude palm oil	4.38
4.13	The constant (α_L, K_L/α_L) and the correlation coefficient (r^2) of the Langmuir equation for carotene adsorption	4.39
4.14	The constant (α_L, K_L/α_L) and the correlation coefficient (r^2) of the	4.39

	Langmuir equation for chlorophyll adsorption	
4.15	**The constants (K_F, 1/n) and the correlation coefficient (r^2) of the Freundlich equation for carotene adsorption**	**4.41**
4.16	**The constants (K_F, 1/n) and the correlation coefficient (r^2) of the Freundlich equation for chlorophyll adsorption**	**4.41**
4.17	**The constants (K_H) and the correlation coefficient (r^2) of the Henry's Law equation for carotene adsorption**	**4.43**
4.18	**The constants (K_H) and the correlation coefficient (r^2) of the Henry's Law equation for chlorophyll adsorption**	**4.43**
A1	**The colour of CPO and CPKO after bleaching using the DSBC**	**A.34**
A2	**Concentrations of residual carotene in degummed-bleached palm oil after bleaching with different dosages of WAC**	**A.34**
A3	**Concentrations of residual chlorophyll in degummed-bleached palm oil after bleaching with different dosages of WAC**	**A.34**
A4	**Error data for adsorption/desorption isotherms of nitrogen of the HRSBC-PO at different temperatures for 1 hr**	**A.49**
A5	**Error data for adsorption/desorption isotherms of nitrogen of the HRSBC-PKO at different temperatures for 1 hr**	**A.50**
A6	**Error data for adsorption/desorption isotherms of nitrogen of the HRSBC-WAC at different temperatures for 1 hr**	**A.51**
A7	**Error data for adsorption/desorption isotherms of nitrogen of the HRSBC-AH at different temperatures for 1 hr**	**A.52**
A8	**Error data for pore size distribution of the HRSBC-PO regenerated at**	**A.53**

	different temperature for 1 hr	
A9	Error data for pore size distribution of the HRSBC-PKO regenerated at different temperature for 1 hr	A.54
A10	Error data for pore size distribution of the HRSBC-WAC regenerated at different temperature for 1 hr	A.55
A11	Error data for pore size distribution of the HRSBC-AH regenerated at different temperature for 1 hr	A.56

LIST OF FIGURES

Figure		*Page*
1.1	Outline of the study	1.4
2.1	Schematic diagram representation of the physical refining process	2.3
2.2	The schematic crystal structure of montmorillonite	2.5
3.1	Apparatus set-up for the laboratory bleaching process	3.6
3.2	Preparation of refined palm oil with bleaching clay	3.8
3.3	Preparation of bleached palm oil for the analysis of adsorption isotherm	3.12
4.1	Deoiling efficiency as a function of solid to solvent ratios	4.5
4.2	Regeneration efficiency as a function of solid to solvent ratios in the the refining of (a) CPO and (b) CPKO	4.7
4.3	Regeneration efficiency of DHRSBC as a function of regeneration temperature	4.8
4.4	Regeneration efficiency of HRSBC-PO and HRSBC-PKO as a function	4.12

	of regeneration temperature	
4.5	Regeneration efficiency of HRSBC of WAC and AH as a function of regeneration temperature	4.13
4.6	Adsorption/desorption isotherms of nitrogen of the HRSBC-PO regenerated at different temperatures for 1 hr	4.21
4.7	Adsorption/desorption isotherms of nitrogen of the HRSBC-PKO regenerated at different temperatures for 1 hr	4.21
4.8	Adsorption/desorption isotherms of nitrogen of the HRSBC of WAC regenerated at different temperatures for 1 hr	4.22
4.9	Adsorption/desorption isotherms of nitrogen of the HRSBC of AH regenerated at different temperatures for 1 hr	4.23
4.10	Pore size distribution of the HRSBC-PO regenerated at different temperatures for 1 hr	4.24
4.11	Pore size distribution of the HRSBC-PKO regenerated at different temperatures for 1 hr	4.25
4.12	Pore size distribution of the HRSBC of WAC regenerated at different temperatures for 1 hr	4.26
4.13	Pore size distribution of the HRSBC of AH at different temperatures for 1 hr	4.27
4.14	Adsorption/desorption isotherms of nitrogen of the different type of HRSBC produced regenerated at temperature of 500°C for 1 hr	4.29
4.15	Pore size distribution of the different type of HRSBC regenerated at temperature of 500°C for 1 hr	4.30
4.16	Adsorption/desorption isotherms of nitrogen of regenerated SBC by different regeneration process at 500°C for 1 hr	4.31
4.17	Pore size distribution of the HRSBC produced by different regeneration process at temperature of 500°C for 1 hr	4.32
4.18	Percentage of weight loss in (a) HRSBC and (b) DHRSBC as a function of regeneration temperature	4.35
4.19	Weight loss of HRSBC of WAC and AH function of regeneration temperature	4.37
4.20	The Langmuir isotherm for adsorption of carotene on HRSBC of WAC at 105°C	4.39
4.21	The Langmuir isotherm for adsorption of chlorophyll on HRSBC of	4.40

	WAC at 105°C	
4.22	The Freundlich isotherm for adsorption of carotene on HRSBC of WAC at 105°C	4.42
4.23	The Freundlich isotherm for adsorption of chlorophyll on HRSBC of WAC at 105°C	4.42
4.24	Linear isotherms for adsorption of carotene on HRSBC of WAC at 105°C	4.44
4.25	Linear isotherms for adsorption of chlorophyll on HRSBC of WAC at 105°C	4.44
A1	Conventional Soxhlet extraction	A.28
A2	ASAP 2010 Micromeritics Physical Instrument	A.28
A3	Carbolite box furnace	A.29
A4	SCOPA apparatus set	A.29
A5	Lovibond Tintometer	A.30
A6	UV-Visible spectrophotometric measurement	A.30
A7	Lifmeter	A.31
A8	Regenerated spent bleaching clay (a) DHRSBC-PO and (b) DHRSBC-PKO from solvent extraction followed by heat treatment	A.32
A9	Refined and crude (a) palm kernel oil and (b) palm oil	A.33
A10	Error bar graph for adsorption/desorption isotherms of nitrogen of the Fresh XMP	A.35
A11	Error bar graph for adsorption/desorption isotherms of nitrogen of the HRSBC-PO regenerated at different temperatures for 1 hr	A.35
A12	Error bar graph for adsorption/desorption isotherms of nitrogen of the HRSBC-PKO regenerated at different temperatures for 1 hr	A.37
A13	Error bar graph for adsorption/desorption isotherms of nitrogen of the Fresh WAC	A.38
A14	Error bar graph for adsorption/desorption isotherms of nitrogen of the HRSBC-WAC regenerated at different temperatures for 1 hr	A.39
A15	Error bar graph for adsorption/desorption isotherms of nitrogen of the Fresh AH	A.40

A16	**Error bar graph for adsorption/desorption isotherms of nitrogen of the HRSBC of AH at different temperatures for 1 hr**	**A.41**
A17	**Error bar graph for pore size distribution of the Fresh XMP**	**A.42**
A18	**Error bar graph for pore size distribution of the HRSBC-PO regenerated at different temperatures for 1 hr**	**A.43**
A19	**Error bar graph for pore size distribution of the HRSBC-PKO regenerated at different temperatures for 1 hr**	**A.44**
A20	**Error bar graph for pore size distribution of the Fresh WAC**	**A.46**
A21	**Error bar graph for pore size distribution of the HRSBC-WAC regenerated at different temperatures for 1 hr**	**A.46**
A22	**Error bar graph for pore size distribution of the Fresh AH**	**A.48**
A23	**Error bar graph for pore size distribution of the HRSBC-AH regenerated at different temperatures for 1 hr**	**A.48**

LIST OF NOTATIONS/SYMBOLS/ABBREVIATIONS

a_s	**Adsorbance of sample**	
a_b	**Cuvette error**	
α_L	**Energy of adsorption**	**L/mg**
C_o	**Initial concentration of solution**	**mg/L**
C_e	**Liquid phase concentration at equilibrium**	**mg/L**
$E^{1\%}_{233c}$	**Specific extinction in UV-light 233 nm**	
$E^{1\%}_{269c}$	**Specific extinction in UV-light 269 nm**	
K_F	**Freundlich adsorption capacity**	**mg/g**
K_H	**Henry's Law constant**	**L/g**
K_L	**Langmuir constant**	**L/g**
n	**Surface heterogeneity**	
P	**Actual gas pressure**	**mmHg**
P_o	**Vapor pressure**	**mmHg**
P/P_o	**Relative pressure**	
q_e	**Solid phase concentration**	**mg/g**
r^2	**Square correlation coefficient**	
R_o	**Red color index of unbleached oil**	
R_r	**Red color index of bleached oil by regenerated clay**	
R_a	**Red color index of bleached oil by fresh clay**	
S_{BET}	**BET specific surface area**	**m^2/g**
V_{total}	**Total pore volume determine at 0.99 P/Po**	**cm^3/g**
V	**Volume of oil**	**L**
ASAP	**Accelerated surface area and porosimetry**	
ASTM	**American Society for Testing and Materials**	
B	**Blue Lovibond unit**	
BDDT	**Brunaller, Deming, Deming and Teller**	
BET	**Brunnauer-Emmet-Teller**	
BJH	**Barret-Joyner-Halenda**	
CPO	**Crude palm oil**	

CPKO	**Crude palm kernel oil**
DHRSBC	**Deoil-heat-regenerated spent bleaching clay**
DOBI	**Deterioration of bleachability index**
DSBC	**Deoiled spent bleaching clay**
EPO	**Oil extracted from spent bleaching clay at palm oil refinery**
EPKO	**Oil extracted from spent bleaching clay at palm kernel oil refinery**
FFA	**Free fatty acid**
g	**gram**
HRSBC	**Heat-regenerated spent bleaching clay**
hrs	**hours**
IUPAC	**International Union of Pure and Applied Chemistry**
IV	**Iodine value**
MPOB	**Malaysian Palm Oil Board**
mins	**minutes**
mmHg	**Milimetre mercury**
nm	**nanometre**
N	**Neutral Lovibond unit**
PORIM	**Palm Oil Research Institute Malaysia**
R	**Red Lovibond unit**
RBD	**Refined, bleached and deodorized oil**
SBC	**Spent bleaching clay**
SCOPA	**Seed Crushers and Oil Produce's Association**
UV	**Ultraviolet**
wt	**Weight**
Y	**Yellow Lovibond unit**

CODE OF SAMPLES

AH	**Attapulgite Hudson**
DHRSBC-WAC400	**DHRSBC of WAC at regeneration temperature of 400°C**
DHRSBC-WAC500	**DHRSBC of WAC at regeneration temperature of 500°C**

DHRSBC-WAC800	**DHRSBC of WAC at regeneration temperature of 800°C**
DHRSBC-AH400	**DHRSBC of AH at regeneration temperature of 400°C**
DHRSBC-AH500	**DHRSBC of AH at regeneration temperature of 500°C**
DHRSBC-AH800	**DHRSBC of AH at regeneration temperature of 800°C**
DHRSBC-PKO400	**DHRSBC of PKO at regeneration temperature of 400°C**
DHRSBC-PKO500	**DHRSBC of PKO at regeneration temperature of 500°C**
DHRSBC-PKO600	**DHRSBC of PKO at regeneration temperature of 600°C**
DHRSBC-PKO800	**DHRSBC of PKO at regeneration temperature of 800°C**
DHRSBC-PKO1000	**DHRSBC of PKO at regeneration temperature of 1000°C**
DHRSBC-PO400	**DHRSBC of PO at regeneration temperature of 400°C**
DHRSBC-PO500	**DHRSBC of PO at regeneration temperature of 500°C**
DHRSBC-PO600	**DHRSBC of PO at regeneration temperature of 600°C**
DHRSBC-PO800	**DHRSBC of PO at regeneration temperature of 800°C**
DHRSBC-PO1000	**DHRSBC of PO at regeneration temperature of 1000°C**
HRSBC-PKO400	**HRSBC of PKO at regeneration temperature of 400°C**
HRSBC-PKO500	**HRSBC of PKO at regeneration temperature of 500°C**
HRSBC-PKO600	**HRSBC of PKO at regeneration temperature of 600°C**
HRSBC-PKO800	**HRSBC of PKO at regeneration temperature of 800°C**
HRSBC-PKO1000	**HRSBC of PKO at regeneration temperature of 1000°C**
HRSBC-PO400	**HRSBC of PO at regeneration temperature of 400°C**
HRSBC-PO500	**HRSBC of PO at regeneration temperature of 500°C**
HRSBC-PO600	**HRSBC of PO at regeneration temperature of 600°C**
HRSBC-PO800	**HRSBC of PO at regeneration temperature of 800°C**
HRSBC-PO1000	**HRSBC of PO at regeneration temperature of 1000°C**
HRSBC-AH400	**HRSBC of AH at regeneration temperature of 400°C**
HRSBC-AH500	**HRSBC of AH at regeneration temperature of 500°C**
HRSBC-AH800	**HRSBC of AH at regeneration temperature of 800°C**
HRSBC-WAC400	**HRSBC of WAC at regeneration temperature of 400°C**
HRSBC-WAC500	**HRSBC of WAC at regeneration temperature of 500°C**
HRSBC-WAC800	**HRSBC of WAC at regeneration temperature of 800°C**
SBC-PKO	**Spent bleaching clay from palm kernel oil refinery**
SBC-PO	**Spent bleaching clay from palm oil refinery**

WAC	**WAC Classic**
XMP	**WAC XMP**