Mineralogical characterization of different clay varieties on behalf of advanced industrial handling

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Abstract: *Clay is a group of minerals that which is more industrial demanded material because of the specific strengths of some components of such clays in the fulfilments of some industrial and technological needs. The chemical composition and other important properties of clays are depended on the origin, location and some other environmental factors. The industrial applications might be varied upon the mineralogy of some of clay. In the existing research, three different types of clay were selected as the materials that namely as anthill clay, brick clay and roof tile clay. The selected types of clay samples were collected from three different regions in Sri Lanka. The collected clay samples were characterized using X-ray fluorescence (XRF) spectrophotometer, Fourier transform infrared (FT-IR) spectrophotometer and optical microscope. According to the investigation results, there were observed the presence of Fe as the most abundant element in all of clays at least 75%, large amounts of kaolinite in three clay types, intermediate amount of quartz and trace amounts of rutile in three clay types. In addition that it is possible to present muscovite in brick clays as a trace mineral and some trace amounts of Fe minerals such as glauconite and marcsite in three clay types. When comparing of the mineralogy of such clays mainly those clays are possible to be further developed as the adsorption materials (adsorber) for the recovering of metals from waste water and polluted air and a recovery material to remove some unnecessary components in chemical processes.*

Keywords*: CLAY, XRF CHARACTERIZATION, FT-IR CHARACTRIZATION, MINERALOGY, CHEMICAL COMPOSITION*

1. Introduction

Clay is an industrially demanded soils species among earth resources because of the distinct properties of such clays foremost of the high porosity and less permeability although the properties and chemical compositions of such clays are varied with the origin and formations. The mineralogy of some clay plays a great role in the industrial applications quits as physico-chemical properties of such clays based on the advanced chemical behaviours of those clays most probably the process of adsorption. In the modern industrialized world, it is highly allured in the development or direct uses of natural materials for advanced industrial handling as composite materials and treated raw materials. Clay is a multi purposely applicable raw material due to the series of physico-chemical varieties and diversity in chemical compositions. Based on those features, those clays may have wide range of applications and those applications may be varied according to the physical and chemical characteristics of specified clays [1, 2, 3, 4, 5, 6]. Therefore, the investigation and analysis of common and advanced characteristics of some selected clay are essential necessity prior of the uses. In the existing research there were expected to investigate and analyze the mineralogy of three different clay species which are available in three different areas in Sri Lanka.

2. Materials and Methodology

As the scopes and objectives of the existing research, three different types of clays were selected as the materials for the study namely as follows and the collected (available) areas are shown in Fig. 1.

- Anthill clay- Using in the building of anthill by termite (A 1- Matale Area in Matale District)
- Brick clay- Using in the manufacturing of bricks (A 2- Maduragoda Area in Kurunegala District)
- Roof tile clay- Using in the manufacturing of roof tiles (A 3- Dankotuwa Area in Puttalam District)

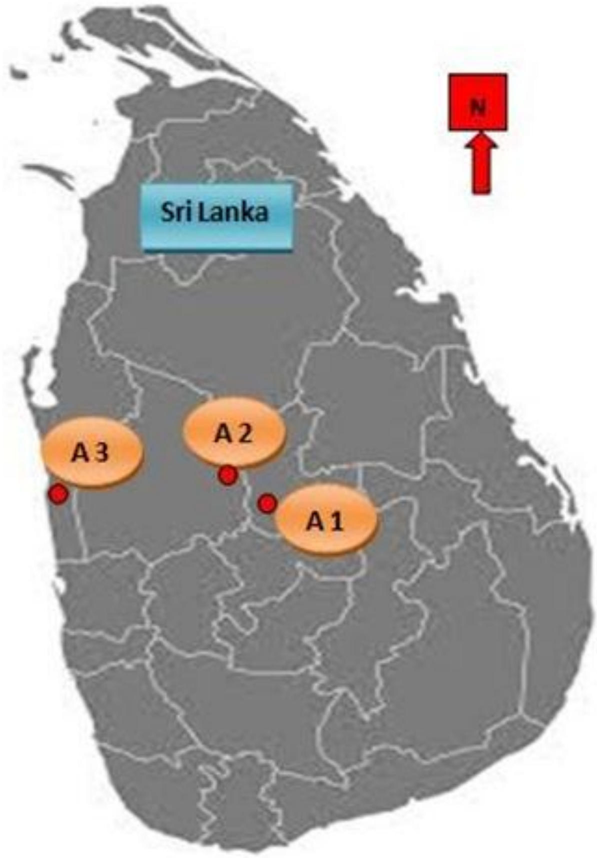

Fig.1. *Clay sample collected areas in Sri Lanka*

The collected clay samples were stored carefully in non-contaminated polythene bags and some representative clay samples from their original clay bulks were separated for the different experiments and those clay samples were prepared according to the standard defined methods for each experiment.

2.1. Elemental analysis

The representative clay samples were oven dried for 24 hours under the temperature of 110^0C until removal of moisture from clays and the dried clay samples were crushed using a ceramic crucible [1-9].

The final representative clay portions were selected using the coning and quartering method which is shown in the Fig. 2.

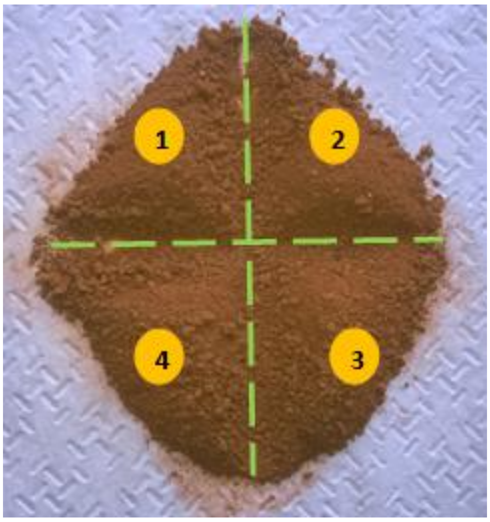

Fig. 2. *Coning and quartering method*

The selected representative clay samples were analyzed using X-ray fluorescence (XRF) spectrometer.

Fig. 3. *X-ray fluorescence (XRF) spectrometer*

2.2. Mineralogy and functional group analysis

A selected raw clay portion was separated from each clay bulk. Each of separated clay portion was separately placed in medium size measuring cylinders and the clay potions were dissolved in distilled water while shaking the system. The shacked system was allowed to settle down after a few minutes shaking period. The status of the setting system was observed throughout about two hours and the top most clay portion of each measuring cylinder was collected using medical droppers. The collected clay portion would be the tiniest portion in of each of clay. The collected clay portions were oven-dried for 24 hours under the temperature of 110^0 C based on the aim of the removal of water and moisture [1-10]. The dried clay samples were crushed using a ceramic crucible to break some clogs and finally a dry clay powder was prepared from each clay type.

The prepared clay samples were analyzed using Fourier transforms infrared (FT-IR) spectrometer.

Fig. 4. *Fourier transforms infrared (FT-IR) spectrometer*

3. Results and Discussion

3.1. Elemental analysis of clays

According to the analysis of X-ray fluorescence (XRF) analysis, the elemental compositions of clays are given in the following figure and tables.

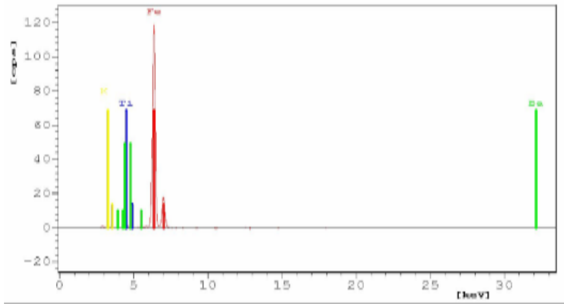

Fig. 5. *X-ray fluoresce (XRF) spectroscopy of anthill clay*

Table 1: *Elemental composition of anthill clay*

Color of the Peak	Element	Atomic Number (amu)	Content (%)
(red)	Iron (Fe)	26	82.08
(blue)	Titanium (Ti)	22	4.84
(green)	Barium (Ba)	56	0.79
(yellow)	Potassium (K)	19	12.28

Based on above results, the higher Fe content was observed with the trace elements of Ti, Ba and K from anthill clay. Usually such elements would be presented in clays as their oxides because of the reaction with water or moisture [1, 2, 4, 5, 6, 10].

In the analysis of observed results, relatively higher Fe content indicates the suitability of some advanced chemical applications such as the adsorption of other metals or catalyst since it is non-toxic [2,4,6,7]. The industrial applications of such clay can be further described with the mineralogy of anthill clay. In addition, the content of K indicates some relatively higher acidity for anthill clay and Ba is non-toxic element whereas Ba^{2+} is highly toxic in aqueous solutions. But that factor may not be considered in the existing study and further researches because the Ba content is trace in anthill clay (<1%) [1-4].

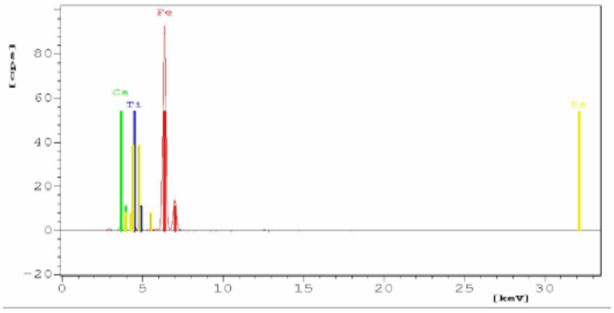

Fig. 6*. X-ray fluoresce (XRF) spectroscopy of brick clay*

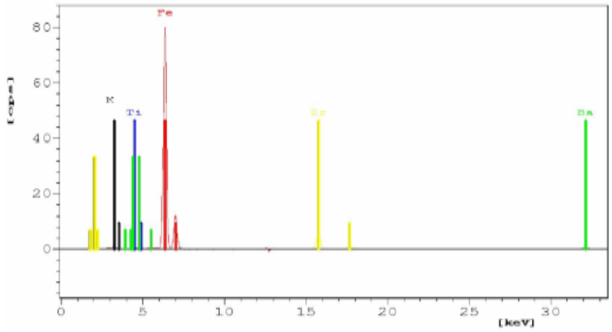

Fig. 7*. X-ray fluoresce (XRF) spectroscopy of roof tile clay*

Table 2: *Elemental composition of brick clay*

Color of the Peak	Element	Atomic Number (amu)	Content (%)
	Iron (Fe)	26	84.38
	Titanium (Ti)	22	5.92
	Calcium (Ca)	20	7.56
	Barium (Ba)	56	2.14

The X-ray fluorescence (XRF) results of brick clay showed the majority of Fe with other trace elements Ti, Ca and Ba. It was not found any K content in brick clay and that observation denotes that the acidity of brick clay should be relatively lower when comparing with other clays which are composed of potassium. The trace content of Ca indicates the plasticity of the clay because the CaO causes the higher plasticity for clays. The plasticity is an indicator for the resistance of such material against the heat [1-6]. Therefore, it is possible to expect some heat resistant applications from brick clays. Apart from that the brick clay may be applied in advanced chemical process which is called as ion exchange because the Ca^{2+} is identified as a foremost exchangeable ion that present in clays or clayey soils.

Ion exchanging is a mechanism which is mostly used in the waste water treatments as a unit operation to remove some unnecessary/undesirable or toxic ions from waste water and the replacing of the removed ions with other necessary/ desirable or non-toxic ions. The possible exchangeable cations which are present in clays are as follows [1, 4, 6, 9, 10, 11, 12].

- Mg^{2+}
- Na^{+}
- K^{+}
- NH_4^{+}
- Ca^{2+}
- H^{+}
- Ba^{2+}

The ion exchange process is usually applicable in the waste water treatments based on following tasks [1-12].

- Reducing or removal of hardness (softening)
- Removal of nitrogen
- Removal of heavy metals
- Desalination of sea water

Table 3: *Elemental composition of roof tile clay*

Color of the Peak	Element	Atomic Number (amu)	Content (%)
	Iron (Fe)	26	75.72
	Titanium (Ti)	22	2.95
	Barium (Ba)	56	5.30
	Zirconium (Zr)	40	3.36
	Potassium (K)	19	12.67

When considering the elemental composition of roof tile clay, it was composed majority of Fe as usual with Ti, Ba, Zr and K. Therefore, it is possible to expect some applications of roof tile clay in followings [1-8].

- Adsorber for some other metals (Fe content)
- Applications in catalytic purposes (porous structure and Fe content)
- Ion exchanging material (Ba^{2+}, Fe^{2+} and K^{+})

In the overall analysis of the elemental compositions of three different clays, some of advanced properties and related applications can be emphasized. However, the applicability of such clays on those tasks would be descriptively confirmed with the mineralogical analysis results forever.

3.2. Mineralogy and functional groups analysis

According to the Fourier transforms infrared (FT-IR) analysis, the FT-IR spectroscopes are shown in following graphs.

Fig. 8. *FT-IR spectroscopy (transmittance) of anthill clay*

The FT-IR spectroscopy (transmittance) of anthill clay showed major peaks at some specific wave number. The descriptions of the relevant functional groups are given in the Table 4.

Table 4: *Functional groups and assignments of anthill clay*

Wave Number (cm^{-1})	Assignment
3695	OH stretching of inner surface hydroxyl groups
3628	OH stretching of structural hydroxyl groups
999	Si-O stretching
910	OH deformations of inner hydroxyl groups
527	Al-O-Si deformation
460	Si-O-Si deformation
411	-

According to the general investigation of the major peaks of the FT-IR spectroscopy of anthill clay, it is possible to conclude that the presence of kaolinite accordingly with the peaks of wave numbers at 3695cm^{-1}, 3628 cm^{-1}, 910 cm^{-1}, 527 $cm^{-1}$and 460 cm^{-1}. Apart from the major clay mineral, it is feasible to identify the mineral muscovite according to the peak of the wave number at 999 cm^{-1}. The muscovite is a mineral which is belonged to the group of mica. It can be distinctively identified because of the white color of that mineral when comparing with the other available colors of minerals in mica group. The chemical formulas of kaolinite and muscovite are given in the below [1, 2, 4, 11, 12].

- Kaolinite - $Al_2(Si_2O_5)(OH)_4$
- Muscovite – $KAl_2(AlSi_3O_{10})(OH)_2$

In the further analysis of the FT-IR spectrum of anthill clay, there would be a probability to present the ferrous mineral which is named as pyrite accordingly with the peak of the wave number at 411 cm^{-1} although it is an insufficient observation to make some fixed conclusion or decision.

Therefore, the anthill clay should be a good adsorber for some other metals because of the presence of kaolinite due to the chemically activation of the functional groups such as the hydroxyl groups. The anthill clay is possible to be recommended for the waste water treatment applications such as the removal of heavy metals and pathogens as well.

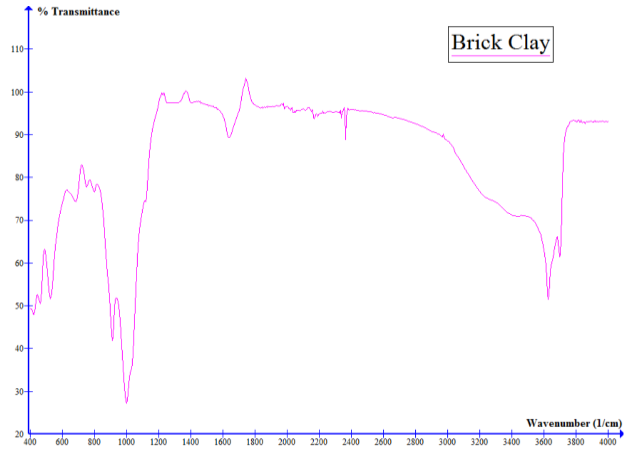

Fig. 9. *FT-IR spectroscopy (transmittance) of brick clay*

Table 5: *Functional groups and assignments of brick clay*

Wave Number (cm^{-1})	Assignment
3702	OH stretching of inner surface hydroxyl groups
3629	OH stretching of structural hydroxyl groups
1001	Si-O stretching
909	OH deformations of inner hydroxyl groups
530	Al-O-Si deformation
469	Si-O-Si deformation
420	-

The FT-IR spectroscopy of brick clay showed the presence of kaolinite because the peaks were identified with respect to the wave numbers at 3702 cm^{-1}, 3629 cm^{-1}, 909 cm^{-1}, 530 $cm^{-1}$and 469 cm^{-1}. The peak of the wave number at 1001 cm^{-1} indicates the present of muscovite in brick clay. Therefore, the industrial applications of brick clay would be same as the anthill clay such as the removal of heavy metals from the waste water [2, 3, 4, 10, 11, 12].

Those clays would be applicable in the removal of following metals from the waste water including heavy metals.

- Cobalt
- Copper
- Nickel
- Manganese
- Arsenic

- Cadmium
- Chromium
- Mercury
- Lead
- Zinc
- Uranium

The metallic contamination of water is a serious incident in the less quality of drinking water which causes some diseases for the human beings and animals. Therefore, the development of clay based treatment systems may be seen in the future.

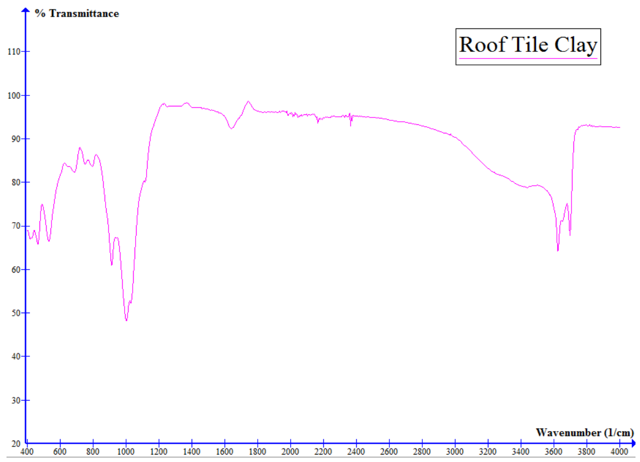

Fig. 10. *FT-IR spectroscopy (transmittance) of roof tile clay*

Table 6: *Functional groups and assignments of roof tile clay*

Wave Number (cm^{-1})	Assignment
3696	OH stretching of inner surface hydroxyl groups
3623	OH stretching of structural hydroxyl groups
1001	Si-O stretching
915	OH deformations of inner hydroxyl groups
530	Al-O-Si deformation
463	Si-O-Si deformation

The presence of kaolinite was confirmed in roof tile clay because of the distributions of peaks of wave numbers at 3696 cm^{-1}, 3623 cm^{-1}, 915 cm^{-1}, 530 cm^{-1} and 463 cm^{-1} as usual. Also the present of muscovite was confirmed referring the peak of wave number at 1001 cm^{-1}. The roof tile clay would also be useful in the industrial purposes such as the treatment of waste water [1, 2, 4, 11].

As the special industrial application for the roof tile clay, it can be expected the applications in the removal of inorganic contaminations from the waste water such as the fluorides because of the presence of zirconium also with clay minerals such as kaolinite [4, 11].

In addition that the major peaks of wave numbers at ~ 450 cm^{-1} and ~1000 cm^{-1}were observed in three spectrums and that evident indicates the presence of quartz in three clay types even as a trace mineral [1, 2, 3, 4, 11].

4. Conclusion

As the results of the existing research, there were obtained at least 75% of Fe in each of clay with some of trace metals such as K, Ba, Ti, Ca and Zr in trace amounts < 13% while observing kaolinite, muscovite and quartz as the major minerals with some ferrous minerals. By considering the results and analysis of the outcomes, it seems that those clays would be some robust raw materials in the industrial applications namely as the ion exchanging material, adsorber, catalyst and heat resistant material.

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6. References

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