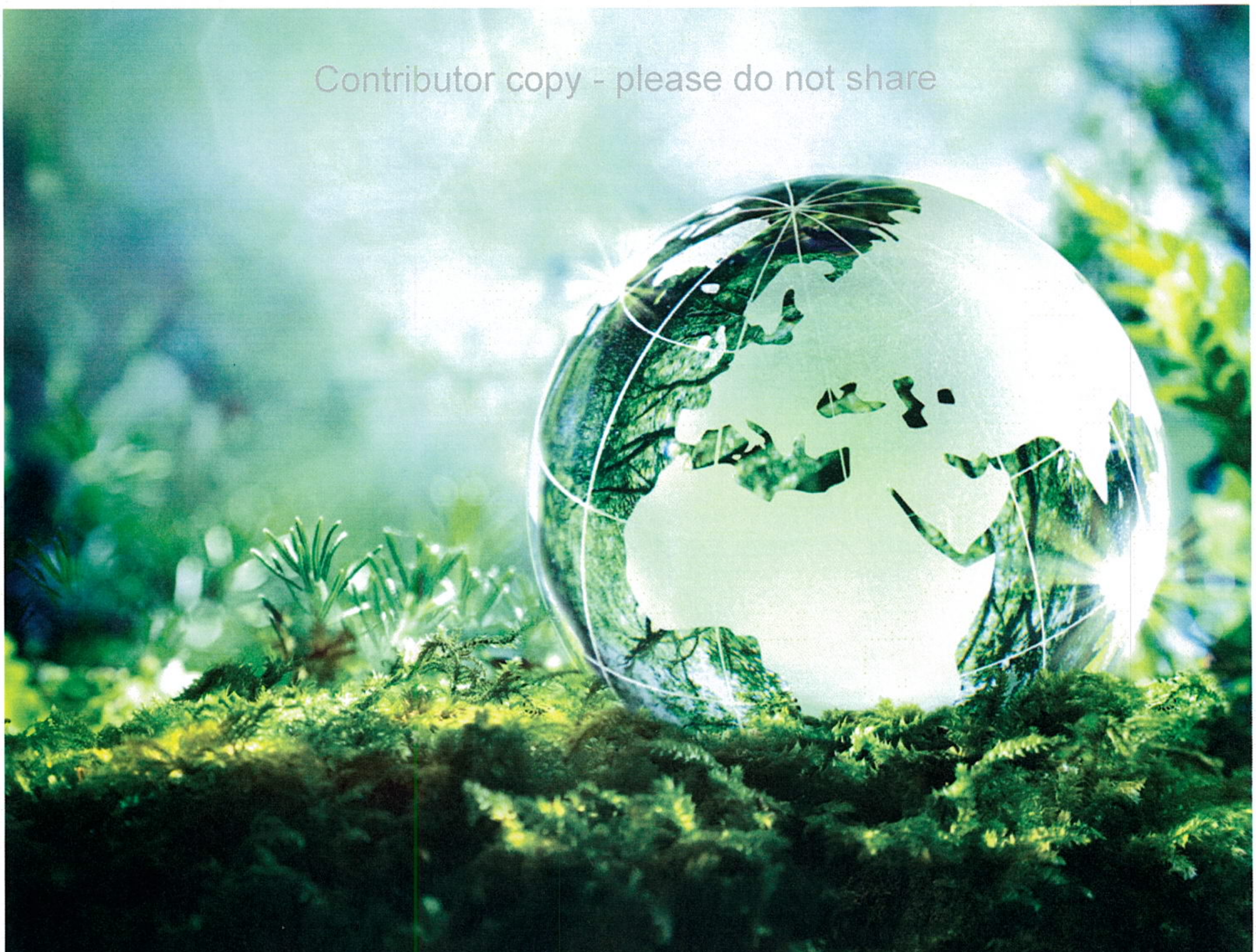

Environmental Conservation, Clean Water, Air & Soil (CleanWAS)

International Conference Proceedings 26-28 August, 2016, China

IWA PUBLISHING

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IWA PUBLISHING

Published by **IWA Publishing**
Alliance House
12 Caxton Street
London SW1H 0QS, UK
Telephone: +44 (0)20 7654 5500
Fax: +44 (0)20 7654 5555
Email: publications@iwap.co.uk
Web: www.iwapublishing.com

First published 2017

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British Library Cataloguing in Publication Data
A CIP catalogue record for this book is available from the British Library

ISBN 9781780408156 (Paperback)
ISBN 9781780408163 (eBook)

Analysis of heavy metals content as a key indicator to predict shallow slope failure

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ABSTRACT

Degradation or decline of soil quality that cause shallow slope failure may occur due to physical or chemical processes. It can be triggered off by natural phenomena, or induced by humans through misuse of land resources, excessive development and urbanization leads to deforestation and erosion of the covered soil masses that causing serious threat to slopes. The extent of damages of the slopes could be minimized if a long-term early warning system to predict the landslide prone areas would have been in place. The aim of the study is to characterize chemical properties of stable and unstable slope along selected highways in Malaysia which can be manipulated as indicator to forecast shallow slope failure. Those elements in soil chemical properties contributed to each other as binding agents that affects the existing soil structure. It could make the soil structure strong or weak .In conclusion, indicators that can be used to predict shallow slope failure are low content of Ferum (Fe), Plumbum (Pb), Aluminum (Al), Chromium (Cr), Zinc (Zn), low content of organic carbon and CEC.

Keywords: Oxisols, soil chemical properties, heavy metal, shallow slope failure, CEC

1 INTRODUCTION

In Malaysia, landslides have always pose threats to settlements and structures which support transportations, natural resources and tourism. The issues regarding landslides have always been closely related to the soil factors (Harwant Singh, 2006). Like all acid soils of the humid tropics such as sandy soil, highly weathered soil (oxisols) soils are low in soil pH, which brings with it many potential problems, including H, Al, and Mn toxicity, Ca deficiency, low CEC, P fixation and low microbial activity (Tessens & Shamshuddin, 1983; Foy, 1984). The shallow top oxsoils are highly susceptible to erosion, if they are not managed properly after clearing. They can also lose much of their original fertility and beneficial physical properties.

The chemical and physical properties of the soil are very important for overall soil stability (Sidle & Ochiai, 2006). Degradation or the decline in soil quality can occur due to physical or chemical processes that were triggered off by natural phenomena or been prompted by humans through the misuse of land resources. There are numerous indicators of soil quality. Physical indicators can be measured by investigating some of the fundamental physical characteristics of the soil such as water infiltration or field water holding capacity while the soils' chemical indicators are determined by given parameters arising from the presence of certain amounts and certain types of soil colloids, such as clays and organic matter (Brady & Weil, 2002). The chemical properties of soils are differ from areas to areas, based on the state or region of the study. The landslide problem might be caused by chemical properties inside the soil which causes the shallow slope failure. Therefore, it is vital to identify and analyze the potential slope failure in the surrounding areas to prevent this from happening.

The study on the chemical properties of soil on hilly area that affects shallow slope failure that focuses on heavy metal content in soils is seen as an action to create a hazard monitoring system to identify potential shallow slope failure areas. In this paper, the researcher attempts to characterize the changes in soils' chemical properties when the soils are exposed for slope terracing. To achieve this, locations with terraced-saprolitic profiles of different geology and locations were selected in two states, Selangor and Perak for further investigation to help forecast the potential of slope failure by using the process of soil chemical analysis.

2 MATERIALS AND METHODS

2.1 Study areas and sampling sites

Two different states of Malaysia were selected as sites studies in this research which are in Perak and Selangor. As in Perak, 8 different locations were identified which the areas specifically focus on the 4 for stable and 4 for unstable slope; all chosen sites were located along the highways (Tanjung Malim Route). Similar to Selangor 13 locations were identified which consist of 10 unstable slope areas and 3 stable slope areas. In total, 21 sites were selected from these 2 different localities in Peninsular Malaysia.

2.2 Method of soil sampling

There were 21 sampling points consisted of 14 samples from unstable slope and 7 samples of from stable slope (0 to 200 mm depth) were collected. Soil samples were air-dried at 80°C for 3 to 4 days and passed through a 2.0 mm (10 meshes) sieve and were stored in plastic bags. After that, about 0.2 g of sample were accurately weighed into a container made of PFA (peruoroalkoxy polymer), which was then placed in a microwave pressure vessel. After the addition of 2.5 ml of concentrated nitric acid and 10 ml of concentrated hydrochloric acid, the samples were digested using microwave power that progressed in the increase of up to 400 W during 40 min. After the cooling process, the solutions were accurately diluted into 50 ml of water. The operating parameters for the working elements were set as recommended by the manufacturer. All solutions were further analyzed in the laboratories through ICP-MS with three triplicates for each sample.

3 RESULTS AND DISCUSSIONS

3.1 Heavy Metal Concentrations (Fe, Al, Cr, Zn, Pb)

(a) Tanjung Malim-Perak

The most obvious feature of the studied area was the high level concentration of Fe and Al in the stable slope areas, in which their values ranged from (775 to 975 mg kg^{-1}) and (263 to 954 mg kg^{-1}) if compared to Al and Fe in unstable slope areas. There was also a significance difference in the presence of chromium

(Cr) in both slope conditions (unstable and stable slope) where, the level of heavy metal Cr was slightly higher in stable slopes rather than in unstable slopes. The level of concentrations of Zn in stable slopes were from (0.019 to 0.067 mg kg^{-1}) while the concentration of Zn in unstable slopes, varied from (0.033 to 0.039 mg kg^{-1}). Meanwhile, the concentration of Pb in the stable slopes were (0.020 to 0.032 mg kg^{-1}) and the concentration of Pb in unstable slope varied from (0.0025 to 0.03 mg kg^{-1}). Metals Al and Fe have the highest concentrations in stable slope area while Cr, Zn and Pb levels showed a slightly higher concentration of the metal in the stable slopes if compared to the unstable slopes. In conclusion, the stable slopes in Perak consist higher concentrations of Fe and Al.

Table 1 Total heavy metal content in soil samples at stable and unstable slope area. Mean value ± standard deviation values from three replicates (n = 3).

	S1-UPSI	**S2-UPSI**	**S3-UPSI**	**S4-P.CITY**
Stable Slope:				
Fe mg kg^{-1}	950 ± 24	975 ± 19	975 ± 3	775 ± 13
Al mg kg^{-1}	954 ± 32	263 ± 193	279 ± 403	281 ± 451
Cr mg kg^{-1}	0.1 ± 0.1	0.066 ± 0.04	0.046 ± 0.06	ND
Zn mg kg^{-1}	0.067 ± 0.01	0.052 ± 0.006	0.039 ± 0.002	0.019 ± 0.003
Pb mg kg^{-1}	0.032± 0.01	0.052± 0.04	0.2± 0.031	0.020 ± 0.013
Points	**S5**	**S6**	**S7**	**S8**
Unstable Slope:				
Fe mg kg^{-1}	11 ± 19	14 ± 5	22 ± 8	27 ± 16
Al mg kg^{-1}	64 ± 17.4	119 ± 60	93 ± 8.6	29 ± 14
Cr mg kg^{-1}	0.056 ± 0.033	0.029 ± 0.07	0.034.6 ± 0.024	0.011 ± 0.001.3
Zn mg kg^{-1}	0.033 ± 0.01	0.051 ± 0.005	0.058 ± 0.018	0.039 ± 0.014
Pb mg kg^{-1}	0.030.7 + 0.002	0.018 ± 0.009	0.018 ± 0.018	0.0025 ± 0.015

(b) Selangor

The result from the T-Test analysis showed a significant difference in Fe, Al, Zn, Cr and Pb concentration in the soils of the stable and unstable slopes. In this study, the concentration of Fe was found to be higher in the stable slopes when compared to the concentration of Fe in unstable slope, with concentration levels between 87 to 110 mg kg^{-1}. Moreover, a high concentration of Al had also been identified in soils at the stable slope area with concentration levels that ranged between 220 to 392 mg kg^{-1}. The concentrations of Al and Fe have significant relationships with Oxisol soil; the degree of Al substitution in iron oxides can reflect the environments in which they are form (Schwertmann & Kampf, 1985; Schwertmann, 1988b). Meanwhile, the concentration level of chromium is quite balanced between the stable and unstable slope. Furthermore, the result shows the concentration of zinc was higher in the stable slopes rather than in the unstable slopes with the concentration starting from 0.007 to 0.76 mg kg^{-1}. Furthermore, the concentration of Pb was higher in the stable slopes, which was from 0.001 to 0.035 mg kg^{-1}. These findings have demonstrated an apparent influence of heavy metals in soils at the stable and unstable slope areas. It can be concluded that, the Fe and Al have the highest concentrations in stable area in Selangor.

Table 2 Total heavy metal content in soil samples at stable slope and unstable slope area. Mean value ± standard deviation values from three replicates (n = 3).

Points	**S1**	**S2**	**S3**
Stable Slope:			
Fe mg kg^{-1}	87 ± 39	187± 236	110 ± 185
Al mg kg^{-1}	392 ± 214	254 ± 14.2	220 ± 256
Cr mg kg^{-1}	0.225 ± 0.166	0.071 ± 0.015	0.0015 ± 0.0025
Zn mg kg^{-1}	0.76 ± 0.022	ND	ND
Pb mg kg^{-1}	0.035 ± 0.002	0.032 ± 0.021	ND

Points	**Fe mg kg^{-1}**	**Al mg kg^{-1}**	**Cr mg kg^{-1}**	**Zn mg kg^{-1}**	**Pb mg kg^{-1}**
Unstable Slope:					
S4	13 ± 3.6	3.2 ± 3.1	ND	ND	ND
S5	0.72 ± 0.38	3.8 ± 2.1	ND	ND	ND
S6	5.1 ± 1.8	3.4 ± 3.5	ND	ND	0.021 ± 0.035
S7	23 ± 6.2	72.9 ± 21.6	0.076 ± 0.021	0.109 ± 0.04	31 ± 10
S8	71 ± 49.3	183 ± 123	0.199 ± 0.133	0.143 ± 0.132	11.4 ± 8.4
S9	42.6 ± 37.2	125 ± 74.5	0.115 ± 0.099	0.097 ± 0.037	6.6 ± 5.6
S10	33 ±1 3	148 ± 64	0.094 ± 0.037	0.094 ± 0.037	5.6 ± 2.3
S11	30.8 ± 4.2	201 ± 15.9	0.087 ± 0.007	0.041 ± 0.024	6.8 ± 0.4
S12	31.9 ± 9.3	144 ± 2.5	ND	0.104 ± 0.077	4.6 ± 1.2
S13	36.7 ± 1.2	129 ± 5.1	0.113 ± 0.005	0.062 ± 0.005	3.8 ± 0.74

ND: Not detected

3.2 The relationship between heavy metal content, CEC, soil texture, organic carbon and shallow slope failure

This analysis showed that a higher content of heavy metal can be an indicator that the soils have more contents of organic carbon and have higher contents of CEC activities, which result in the stability level of the soil. This is because; despite of the laterisation process, the tissues from the existing plantings on the slopes can be deposited into the soil through leaves litters and the build ups of organic soil matters. The contents of the organic matter will increase the CEC activities and micronutrients in the soils. Therefore, lower contents of heavy metals show that the soil has a lower content of organic carbon and a lower content of CEC activities. This resulted in the instability of the soil. This type of soil will go through a rapid process of laterisation. In this process, the primary mineral will most probably absent and contribute to low CEC activities, low micronutrients and low moisture retention, or low water holding capacity. The soil eventually becomes very acidic, infertile and unstable.

Based on this result, the total content of Aluminium (Al), Zinc (Zn), Ferum (Fe) and Plumbum (Pb) are higher in the soils from stable slope if compare to the soils from unstable slope from both states. Moreover, the heavy metal contents usually decreased from clay to coarse silt. This is caused by the high surface area of clay minerals and the weak pH depending on the CEC activities. Soils with high amount of clay and organic matters can contribute more heavy metal than others. Hence, the present of high clay contents contributed to the results of high CEC contents in unstable slopes. This caused the positively charged heavy metal contents are bonded with the high clay contents, which are negatively charged (Dube, 2000). The conditions contribute to the stability of the soil since the negative clay ions and positive ions of heavy metal contents are bonded to each other. In addition, Jamal and Nuranina (2005) stated that nitrogen and CEC contents correlated significantly to the aggregate stability by regarding the clay contents in soils.

It can be concluded that heavy metal contents are higher instable slopes than in the unstable slopes. These results clearly demonstrated that the concentrations of heavy metal in different slope conditions can have important influences on the shallow slope failures. Furthermore, the results of the study showed that a higher content of heavy metal was an indication that the soil has a higher content of organic carbon and CEC which result in the stability of the soil. Therefore, lower content of heavy metal is an indication that the soil has lower content of CEC which result in the instability of the soil which had proven the facts stated by Singer and Munns (2002), Jamal and Nuraina (2005), and Dube (2000). Finally, the key indicator to predict shallow slope failure based on soil chemical properties for 21 sites are clearly summarized in Table 3.

Table 3 Key indicator to predict shallow slope failure based on soil chemical properties for 21 sites.

		Unstable Slope				**Stable Slope**			
Class		**I**		**II**	**III**	**I**		**II**	**III**
Heavy metal	Fe + 3	20	50	100	150	500	1000	1500	3500
	Al + 3	200	250	350	400	600	800	1000	1600
	Zn + 2	0.1	0.2	0.3	0.35	0.05	0.06	0.08	0.09
	Pb + 4	0.05	10	20	28	30	35	40	46
	Cr + 3	0.08	0.09	0.1	0.2	0.3	0.4	0.5	0.6

Unstable slope: Class I = High risk Class, Class II = Medium risk, Class III = Low risk.
Stable slope: Class I = Less Stable, Class II = Stable, Class III = Most Stable.

4 CONCLUSION

To recapitulate, it could be said that heavy metal content in are closely related to the stability of the slope. It can be an effective hazard monitoring rating system and can further lengthen the time for shallow slope failure to occur on the indicated area of slope failure. Through this study, we can examine each of those components, and explores the importance of soil chemical and what it can tell us about soil conditions such as fertility and drainage that play an important aspect in influencing the stability of the slope. Basically, there are several ways by which we can improve the poor condition of soil chemical properties that cause shallow slope failure such as by improving drainage to speed soil drying and reduce saturation during wet periods. The technique of surface mulching around trees is also an effective method of improving soils conditions. Mulch will extend to the drip line when possible. Furthermore, organic amendments can also benefit the soils in several ways, such as by increasing nutrients and water-holding capacities as well as improving drainage and aeration of the soils. This will enable the provision of a good soil environment for plant growth that plays important roles in enhancing the stability of the newly cut slope and matured slope. Finally, with this result, it is hope that this research will provide the informative information for the local authority and also to other non-government related agencies about new finding for landslide disaster management. The results are designed to provide some clarification of the assessment tools for shallow slope failure which in turn will assist all relevant stakeholders including engineer, developers and government bodies in making informed decisions when designing new cut slope as well as in monitoring and managing the existing slope.

5 ACKNOWLEDGEMENTS

The authors would like to thanks Ministry of Education (MOE) and International Islamic University Malaysia (IIUM) for the Research Grant NRGS13-002-0002.

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ISBN: 9781780408156 (Paperback)
ISBN: 9781780408163 (eBook)

ISBN 978-1-78040-815-6
90000
9 781780 408156