

The necessity of ascertaining contamination by dust using soil spectral reflectance as its indicator

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Abstract. Pollution of the urban environment by human disturbances and activities is a negative externality of urbanization, therefore becoming a great concern due to the serious problems associated with human health. The mobilization of heavy metals into the biosphere by human activities has become an important process in the geochemical recycling of these metals. Though the risks of exposure to road dust have been reported to be higher for individuals than those in soil, little attention has been paid to the occurrence characteristics of heavy metals in dust and its associated health risks to the population. In the present studies, the physical, chemical and spectral signatures gained from dust and soil constituents would be differentiated based on their reflectance in specific bands of the electromagnetic spectrum. It is expected that the analysis of road dust and soil samples will indicate spectral signatures exhibiting differences in specific wavelengths of the spectrum, hence, indicating their spectral discrimination, as well as the presence of heavy metals showing its reflectance based on its concentration. The expected outcome of this study can be used to provide a theoretical basis for controlling the risk of heavy metals exposure to population.

1 Introduction

Nearly half of the world's population now live-in urban agglomerations requiring frequent development of environment through rapid urbanization and industrialization [1]. Intensive human disturbances is a major factor that intricate the biological system of the metropolitan climate. These intensive activities result in the growing quantities of contaminants such as dust into the urban environment. In a minute and fine state of subdivision, dust consists of solid matter such that the fragments are small enough to be lifted and borne by wind. WHO [2] defines dusts as solid particles, ranging in size from below 1µm up to at least 100µm, which may be or become airborne, due to their origin, physical characteristics and ambient conditions. Dust is a common air pollutant generated by many different sources and activities. Road or street dusts are alluded as residue particles that are stored from the environment and gather alongside roads.

Numerous studies focused on the concentration, source, and health risks of various heavy metals in the soil-dust system in urban ecosystems. It has been documented that mercury-dust deposits on vegetation and human health, suggest that the effects of dust may be important and are worthy of greater research attention [3, 4]. It is therefore imperative to analyze for the presence of heavy metals like mercury and its contamination levels in roadside dust using soil spectral reflectance, and the resultant health effects on people living around or using locations or spaces with dusts. The results from this study can be used to improve the efficiency of dust and heavy metals like mercury pollution control in multi-environmental media during urbanization and provide a theoretical basis for controlling the risk of mercury exposure to urban residents.

2 DUST PROPERTIES AND METHODS OF STUDYING

2.1 Sources of dust

Dust is a vital environmental indicator of heavy metal contamination from atmospheric deposition, and may originate from various stationary and mobile sources such as vehicular traffic, industrial activities, power plants, residential fossil fuel burning, waste incineration, construction and demolition activities, and resuspension of contaminated soil [5, 6]. Consequently, urban surface dust is largely deposited on the urban impervious surface originating from urban atmospheric deposition, soil, traffic, construction dust, and combustion [7].

2.2 Effect on the health of population

The mobilization of heavy metals into the biosphere by human activities has become an important process in the geochemical recycling of these metals [8]. Among the foremost vital consideration in the management of urban surroundings has been dust found on the impervious urban surfaces. The most vulnerable people who are affected by these dusts are the elderly as well as children since their immune systems are immature and age-compromised, respectively [9]. Dusts from the various activities and sources can get through people's bodies by re-suspension-inhalation, hand-mouth ingestion, or through dermal contact, thereby endangering people's health. Also, very small dust particles are more likely to penetrate deeper into the lungs while ultrafine particles can be absorbed directly into the blood stream. Thus, during inhalation and exhalation, the dust undergo inflammation, and even scar the lungs and tissue. Aside the dust gaining access to the lungs through its tiny air sacs, other organs gets affected through blood circulation. Effective functioning of organs and the secretor system could be affected negatively, if heavy metal amass in fatty tissues. Most metals have also been found to cause mutagenic, teratogenic and carcinogenic effects in living beings [9].

2.3 Physical characteristics of dusts

Dust consists of solid particles, mostly of natural or industrial origin, typically formed by disintegration processes. Dust particles may vary in size from 0.01 micron in diameter (for example- carbon black) to nearly 1000 microns (some foundry dusts). Many contaminants, including metals, are found at higher concentrations in finer particles than in coarser particles, and finer particles are more likely to be re-suspended in the air or entrained in rainfall runoff than coarser particles. Dust particles are frequently found with dimensions

considerably <1 mm and, for these, settling due to gravity practically. Dust plays an important role in the middle and upper troposphere, giving rise to additional warming [10].

2.4. Chemical composition of dusts

In considering impacts, chemical makeup and size are vital. For dusts, both composition and size vary greatly over space and time. Fedotov et al. [11] noted that the composition of street dust varies and it is prejudiced by climatic conditions, soil environment, bedrock and anthropic activity. Dust is a vital environmental indicator of the level and distribution of heavy metal contamination in the surface environment. Dust particles of anthropogenic origin usually contain three different kinds of Fe-rich particles deriving from both combustion-related and non-exhaust vehicular sources: irregularly shaped grains and spherules of Fe-oxides (industrial combustion processes), and particles consisting of metallic Fe [12]. According to [13], street dust may contain up to 60% of particles originated in soil: quartz, feldspars (albite, microcline and others), clay minerals, chlorite and muscovite. Gunawardana et al. [14] also indicated that up to 30% of street dust is formed by the amorphous phase, which differs from the amorphous phase common in soils and originates apparently in transport activities. According to Adachi and Tainosho [7], dust contains heavy metal particles such as Fe, Cu, Zr, Sb, Pb etc., and have particle diameter of about $1\mu\text{m}$ that contributes toxic pollutant to the air.

2.5 Methods of dust studying

Traditional techniques for assessing environmental heavy metal contamination in dust typically include field-based soil/sediment sampling, wet chemical digestion and subsequent laboratory analysis, followed by interpolating outputs to create spatial risk maps [15]. However, such approaches are time-consuming and often very expensive [8]. Soil properties, presence and concentration of heavy metals in dust can also be determined using hyperspectral imaging techniques since these are able to offer spectrally-rich and spatially-continuous information that can be utilized for mapping and monitoring of soil contamination. Based on science estimates, spectro-radiometry has been found to be moderately more practicable than the conventional measurement.

2.6 Dust collection methods and analysis

The collection of dust using vacuum cleaner bags has been investigated to be useful in obtaining large quantity of dust compared to passive sampling methods. This method is particularly useful for the isolation of the respirable particle fraction of dust, as large quantities of dust are required to be successful in isolation of material for the analyses performed herein. Still, this technique has certain disadvantages, such as not properly collecting some fine and ultrafine dust particles from the vacuum cleaning bags and further, contamination from inner parts of commercial vacuum cleaner bags and vacuum cleaners may occur [16]. Scanning electron microscopy (SEM) can also be employed for the characterization of morphology and size of the road dust particles. Quanta FEG 450 (FEI) with EDS analysis APOLLO X (EDX) can also be utilized to obtain images of the sample structure and information on elemental composition achieved by point analysis. Phase composition of road dust particles has been documented to be determined using X-ray fluorescence spectroscopy equipped with 50 W Pd X-ray tube.

3 Conclusion

The presence and level of contamination by heavy metals in dust will be investigated in this study. The effect of contamination will be studied by analyzing the data obtained from the spectral reflectance of air dust on roadside surfaces and different types of soils. The spectral signatures gained from the samples would be differentiated based on their reflectance in specific bands of the electromagnetic spectrum and subsequently compared with the quality guidelines values permissible in our urban ecosystem. It is expected that the concentration and levels of heavy metals in air dust and soil will be higher than the permissible levels. This could pose health hazard to urban residents especially children and the old aged due to their under-developed and weak immune systems respectfully through exposure to contaminated soil and dust through inhalation and skin contacts.

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