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*Review*

# Microbiological and health related perspectives of geophagia: An overview

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**Geophagia, which refers to the deliberate eating of soil, is considered to be a deviant eating disorder, a sequel to poverty and famine but could also be observed in the absence of hunger and in both scenarios may be associated with high degree of mortality and morbidity. The phenomenon has been reported to be common among pregnant women, lactating women, school children and people with psychiatric disorders. The microbiology of soil shows a broad diversity and functionality of soil microflora which impact variously on soil and its consumption. Soil microbes contribute immensely to the quality of soil and even determine soil types. Geophagia may be beneficial or harmful. Beneficial aspects include the use of kaolin to treat diarrhea, gastritis, colitis, enhancement of bioactivities and maintenance of normal intestinal flora by commensal flora found in soil. Clay or soil containing special constituents are valuable oral and topical antimicrobials as well as adsorbents of toxins. Microbiological underpinnings of geophagia include the ingestion of eggs of parasitic worms such as *Ascaris lumbricoides, Trichuris trichiura* with the health consequences. Highly toxigenic bacteria such as *Clostridium perfringens*, *Clostridium tetani, Clostridium botulinum,* the causative agents of gas gangrene, tetanus and botulism and other human pathogens may be ingested. It has also been postulated that indirect consumption of soil may pose serious health problems. For example, nitrate run-off and leaching from soil into water bodies may lead to eutrophication and colonization by toxic cyanobacteria with ripple medical effects such as gastroenteritis. Some general health implications of geophagia include association with iron deficiency and anemia, intestinal obstruction, constipation, peritonitis, dental damage, eclampsia, iron deficiency and even mortality. The interplay of factors involved in geophagia, though varied, intricate and researched may not have been fully elucidated. Further concerted efforts aimed at multidisciplinary research are warranted so as to address gaps in the corpus of knowledge on the important subject.**

**Key words:** Geohelminths, geophagia, health, microorganisms, soil.

## INTRODUCTION

There have always been various interplays among humans, animals, plants, earth resources, environmental factors and land use. The impacts of the physical components on biotic life vary and have long been recognized. Today, links between the natural environment and health can be found throughout the world (Bowman et al., 2003). The geology of an area has a direct impact on the regional input of elements into the soil, air and water. Soil or clay plays a pivotal role in the biogeochemical cycle. It acts as a reservoir for mineral elements which may be vital to plant and animal lives. For instance, World Health Organization (WHO, 1996) emphasized the fact that deficiencies of zinc (Zn) due to calcareous soil-type and leached arenaceous soils of low Zn content may lead to anomalies in human food chains. Water for both domestic and other purposes is filtered through the soil and so are elements that are both essential and harmful to human

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and animal health.

Apart from mineral elements, soil or clay serves as reservoir of chemical and biological agents. Among the chemical agents are heavy metals, radioactive gases and organic chemicals. Biologically, soil is the habitat of numerous microorganisms and other higher living organisms. These include beneficial microorganisms such as *Rhizobium* spp. - nitrogen fixing microorganism and pathogens such as *Clostridium tetani* and parasitic worms. Soil, its usage, consumption, impact on health is of grave importance. The interrelatedness of environmental factors such as soil to public health is recognized by the WHO and this prompted the acceptance in 2002 of the conception of sustainable development on the basis of social health development (WHO, 2002). The main essentials of this concept are to keep a balance between the domains of social, economic, ecological life and health in order to ensure the quality of life.

As much as these vital issues are concerned, comprehensive reviews of the soil in relation to health, particularly those which concern deliberate or purposeful eating of soil (geophagia) and the microbiology involved are scarce. In southern Africa, geophagia is a phenomenon that has become a day to day habit particularly among females, yet the microbiology and allied aspects of this practice has not been well researched or documented. This communication seeks to give an overview of the importance of soil with particular emphasis on its microbial components as it impacts on the eating of soil- an age long practice which seems practically unstoppable. The review evaluated the implications of geophagia on human health as a precursor to undertaking a multi-disciplinary study on the subject matter with the overall aim of having safe soil for healthier community consumption.

## MICROBIOLOGICAL ASPECTS OF SOILS

Soils can vary tremendously as to their types and numbers of microorganisms. The soils, in fact are excellent culture media for the growth of various organisms due to the availability of nutrients, water, organic and inorganic matter. Most microbial groups are represented in the soil. Bacteria are the most numerous group of soil microbes (http://www.studentsguide.in/microbiology/soilmicrobiology/bacteria-in-soil.html). Also abundant in soil are fungi, protozoa, viruses, prions and the archaebacteria. The prokaryotic actinomycetes are responsible for the "musty" smell of freshly turned soil. Microalgae are mostly photo-synthetic and their requirements for light makes them most abundant in the top inch of the soil and develop most abundantly when the soil is not heavily shaded by vegetation or surface litter.

Soil microorganisms have been classified as beneficial or harmful in line with their functions and their impact on soil quality, plant growth, animal and human health.

According to Higa and Parr (1994), beneficial micro-organisms embody a large group of often unknown or ill defined microorganisms that interact favorably in soils and with plants to render beneficial effects which are sometimes difficult to predict. Contrariwise, harmful micro-organisms are those that can induce plant diseases, stimulate soil-borne pathogens, immobilize nutrients, and produce toxic and putrescent substances that may adversely affect growth and health of human, plants and animals. Some of the beneficial factors arise as a result of the metabolic activities of most soil microbes which qualify them as production factory. Soil micro-organisms are the main producers of natural antibiotics. More than 50% of the antibiotics which have been described are produced by members of only one soil bacterial order, Actinomycetales, and particularly by one genus of this order, Streptomyces (Abrahams, 2002). Soil microbes can biodegrade recalcitrant pesticides (Ragnarsdottir, 2000), remove or transform organic toxicants in soil and help as mop ups in oil-spillages, thereby providing “natural attenuation” approach to the remediation of contaminated soil (NRC, 1993, 2000). Soil microorganisms have reportedly played role in determining the sorption of radionuclides within organic soil systems (Parekh et al., 2008) and biotransformation of alcohol in soil (Liu et al., 2007). These manipulative activities of soil microbes influence to a large extent what soil eaters may be exposed to. With these vast array of soil microbiota and their machineries, geophagia is hence, a practice worth attention either from a beneficial or harmful microbes perspectives.

## EPIDEMIOLOGICAL ASPECT OF HUMAN GEOPHAGIA

The phenomenon of soil ingestion may be deliberate or non-deliberate. Soil and its components get into human and animals through various pathways which could be direct or indirect. Some of the direct pathways include geophagia, soil in association with edibles, inhalation of dust, inhalation of soil gases, and assimilation of soil components by skin lesions. Also, components of soil may be acquired through water sources; particularly of importance is the ‘biomagnification’ of chemical such as pesticides and their detrimental effects. Any of these pathways can also be route of pathogens and exposure to hazard (Fergusson et al., 1986; Juozulynas et al., 2008; Wagner, 1980).

Studies have shown the antiquity and worldwide distri-bution of geophagia. There are indications that the phenomenon is not restricted to any particular age group, race, sex, geographic region, or time period (Anell and Lagercrantz, 1958; Cooper, 1957; Laufer, 1930), although young children are particularly vulnerable to the habit of soil-eating. Children under the age of 18-20 months normally explore and acquaint themselves with the environment by mouthing everything they come across

(Fessler and Abrams, 2004). Beyond this age however, deliberate soil-eating is often considered abnormal (Abrahams, 2002).

Generally, geophagia is a traditional cultural or religious activity (Vermeer and Frate, 1979), which has been observed during pregnancy (Woywodt and Kiss, 1999), or as a remedy for disease (Vermeer and Ferrell, 1985; Dominy et al., 2004). Culturally speaking, the practice amongst many of the kaolin eaters emanates from having doubtless watched their mothers or close relations eat the clay. Many of the studies on geophagia have advanced many more other reasons for this phenomenon around the world. In the Southern parts of USA, pregnant women who traditionally ate substances like clay, corn starch and baking soda believed that such substances helped to prevent vomiting, helped babies to thrive, cured swollen legs and ensured beautiful children (Mcloughlin, 1987). Many pregnant women in rural southern Georgia eat kaolin or grayish native clay to Georgia. They crave the "dirt" and claim that it helps quite their pregnancy sickness and makes them feel better (Corwin, 1999).

Clay eating is widespread among women in Africa but in particular five African countries namely Malawi, Zambia, Zimbabwe, Swaziland and South Africa, where an estimated prevalence level in the rural areas of these countries is put at 90% (Walker et al., 1997). In South Africa, the eating of clay is mostly observed among pregnant women. The prevalence of pica among urban and rural black South African women was reported to be 38.3 and 44.0% respectively as compared to the prevalence among the Indian, coloured and white women put at 2.2, 4.4 and 1.6%, respectively (Walker et al., 1997). Studies have also established that geophagia is rife among the Tanzanians and Kenyans in the Eastern part of Africa (Young et al., 2007). A particular study by Louba et al. (2004) among 827 pregnant women in western Kenya during and after pregnancy showed that a significant number of these women (65%) reported earth-eating before pregnancy. The prevalence remained high during pregnancy, and then declined to 34.5 and 29.6% at 3 and 6 months post-partum, respectively. Analysis of random stool samples from the study group revealed that faecal silica and geophagia were strongly correlated. Geisler et al. (1998) also reported geophagia as a risk factor for heliminthiasis in Kenyan school children. Geophagia has also been reported in Senegal, Mali (Medilink, 2004), Guinea (Glickman et al., 1999) as well as Nigeria (Ademuwagun et al., 1979) in West Africa.

Gilardi and co-investigators quoted by Diamond (1999) noted that there are preferred soils as far as soil-eating is concerned. Several soil types are consumed by geophagic individuals. These include red, white, yellow, brown clay types, termite mounds and various other types of soil. In Australia, some aborigines eat white clay found mostly in the billabounds of the coastal areas of the North territory, fresh water springs and riverbeds mainly for medicinal purposes (Beteson and Lebroy, 1978). The preferred type of earth eaten by Kenyan women according to Louba et al. (2004) was soft stone, known locally as odowa and earth from termite mounds.

## MICROBIOLOGICAL BENEFITS OF HUMAN GEOPHAGIC PRACTICE

Clay-rich soils have been reported to adsorb intestinal unwanted substances (Dominy et al., 2004). Microbial agents such as *Yersinia enterocolitica*, *Escherichia coli*, *Streptococcus faecalis*, *Helicobacter pylori*, and Mycobacteria have been postulated to play a role in the aetiology of Crohn's disease which is characterized by a severe, non-specific, chronic inflammation of the intestinal wall (Liu et al., 1995; Rubery, 2002; Lamps et al., 2003). According to Shanahan (2000), alterations of the flora with probiotics and antibiotic strategies have putative beneficial effects in human beings and other animals. Several studies have emphasized the role of probiotic bacteria to favorably alter the intestinal microflora balance, inhibit the growth of harmful bacteria, promote good digestion, boost immune function, and increase resistance to infection (Mel'nikova et al., 1993; Sirnov et al., 1993; Walker, 1997). According to the report of Walker, Primal Defence$^{TM}$, a food supplement made up of homeostatic soil organisms (HSOs) help maintain a healthy balance of intestinal flora. (http://www.crohns-disease-probiotics.com/primaldefense.html). This is done by producing organic compounds such as lactic acid, hydrogen peroxide and acetic acid, which increase the acidity of the intestine and inhibit the reproduction of massive amounts of harmful microorganisms (Kawase, 1982; Rasic, 1983). The HSOs$^{TM}$ comprises of up to 15 soil and plants derived microbes such as *Lactobacillus acidophilus, Lactobacillus bulgaricus, Lactobacillus delbreukii, Lactobacillus caseii, Lactobacillus plantarum, Lactobacillus brevis, Lactobacillus lactis, Bacillus licheniformus, Bacillus subtilis, Bifido bifidus, Sacchromyces boulardi.* There is therefore, evidence that supports the usefulness of the commensal flora found in soil as vital in the establishment of healthy bacteria within the digestive tract, addressing the problems presented by Crohn's disease and leaky gut syndrome.

Just as charcoal is prescribed in cases of child poisoning for its adsorptive role, ingested clay in pregnant women may improve digestive efficiency and also reduce fetal exposure to toxins tolerated by mother (Profet, 1992). Aflatoxin is a known toxin produced by fungi. There have been reports of the amelioration of the toxic effect of aflatoxin (Rosa et al., 2001), afflatoxin and fumonisin (Miazzo et al., 2005) in animal feeds by the addition of sodium bentonite to the broiler chick diets. Some specific beneficial pharmaceutical usage of edible soil includes that of white clay (kaolin) mined in Georgia and South Carolina used in the production of Mist Kaolin, a diarrhea remedy (Martindale, 1993).

Methicillin-resistant *Staphylococcus aureus* (MRSA) infections which are no more nosocomial based but spreading to the communities, are increasingly resistant to multiple antibiotics and cause thousands of deaths each year (Klein et al., 2007; Boucher and Corey, 2008). Studies have reported that minerals from clay could provide inexpensive, highly-effective antimicrobials to fight numerous human bacteria infections including the superbug MRSA (Haydel et al., 2008; Williams et al., 2008) and buruli ulcer an infection caused by *Mycobacterium ulcerans* which has been declared to be "an emerging public health threat" by the WHO (1998). The bacterium produces a potent immunosuppressant toxin that causes necrotic lesions and destroys the fatty tissues under the skin. According to Haydel et al. (2008), specific clay minerals may prove valuable in the treatment of Buruli ulcer and other bacterial diseases, for which there are no effective antibiotics. The outcome of the study by Mphuchane et al. (2008) is also that soil or clay contains constituents which possess antimicrobial properties.

The role of microbial degrading enzymes in rendering antibiotics in-effective is a well known mechanism of antibiotic resistance. Soil colloids and minerals have been reported to provide protection to DNA against degradation and this is dependent on the mineralogy of the soil (Cai et al., 2006). According to the study, higher level of protection was found with montmorillonite and organic clays compared to kaolinite and inorganic clays.

## MICROBIOLOGICAL HAZARD OF HUMAN GEOPHAGIC PRACTICE

From a microbiological point of view, various risks are associated with soil eating. That soil harbour so many pathogenic microorganism is no mere speculation but a fact. Isolation of human pathogens from soil dated back to several decades. These pathogens include *Sporotrichum schenckii* (De Beurman and Gougerot, 1908; Emmons, 1951), *Histoplasma capsulatum* (Emmons, 1949), and *Cryptococcus neoformans* (Emmons, 1951) while some latest novel isolations include medically important action-mycetes (Aghamirian and Ghiasian, 2009). A recent molecular characterization of a novel clinical isolate of *Francisella* spp. (the causative pathogen of tularemia) showed genetic relatedness to species of the pathogen cloned from soil sample (Kugeler and Mead, 2008). Therefore, a lot of pathogenic microorganism which are resident in soil can be detrimental to health if such soil is consumed.

Anemia resulting from geophagia, to which the craving for soil is attributed, is believed in some cases to have actually resulted from the worm or microbial infection encountered by ingestion of soil. The global burden of geohelminth infections is of great enormity. Worldwide, there are approximately 3.5 billion infections with parasitic geohelminths: *Ascaris, Trichuris*, and hookworm (Chan, 1997). The eggs of parasitic worms (geohelminths) can be consumed with ingestion of soil. Ascariasis (characterized by abdominal pain and nausea with disturbed functioning of the alimentary tract) and trichiuriasis are caused by the ingestion of *Ascaris lumbricoides* and *Trichuris trichiura* eggs, respectively (Abrahams, 2002). Several studies have linked geohelminths infection with soil consumption. Geohelminths infection was linked to iron-deficiency among HIV-infected women who indulge in geophagia (Kawai et al., 2009). Separate studies on geophagous children in Jamaica (Wong et al., 1991) and Kenya (Geissler et al., 1998) reportedly gave a quantitative estimate of the level of exposure to intestinal *A. lumbricoides* and *T. trichiura* infection experienced by the children. The highlights of the study conducted by Saathoff et al. (2002) were the social pattern of geophagia and its possible role in the transmission of *A. lumbricoides, T. trichiura* and hookworm in a rural area of South Africa. Soil-eating was less frequent in boys, in which group it decreased with age, than in girls, where no such age trend was apparent. The baseline prevalence of *A. lumbricoides* infection in the study was compared based on the choice of soil type consumed; this was higher in pupils who regularly ate soil from termite mounds, when compared with non-geophageous pupils. In contrast, it was markedly lower in the groups who preferred eating tree termite soil. Geophagia according to Glickman et al. (1999) is an important risk factor for orally acquired nematode infections in African children. However, a contrary report by Young et al. (2007) found no correlation between geophagia and helminthes infection in pregnant women in Tanzania.

The spore-bearing *Clostridium perfringens* and *C. tetani* are often encountered in the surface layers of soil (and in human and animal excreta). They are particularly abundant in cultivated and manured fields, especially in the tropics (Abrahams, 2002). These bacilli belonging to the family of bacteria which produce one of the deadliest toxins often cause infections by contamination of wounds exposed to the spore-bearing soil. *C. tetani* is the causative organism of tetanus while *C. perfringens* is the etiology of gas gangrene. Occupations may be a predisposing factor to tetanus, as in the case of soldiers and farmers hence, more tetanus can be expected in rural areas where manual labour is intense. However, people living in rural communities who probably ingest regular quantities of *C. tetani,* develop natural immunity through mouth and gut absorption and thus get protected from tetanus (Sanders, 1996).

Soil as a reservoir for many microbes has been implicated as one of the sources and vehicles by which many human pathogens are transmitted. *Mycobacterium avium* subspecies *paratuberculosis* which is present in many dairy herds could be transmitted to humans via foodstuff and via direct contact with contaminated soil (Herrewegh et al., 2004). The findings of Green et al. (1974) were that soil is a reservoir for *Pseudomonas aeruginosa* and that the bacterium has the capacity to colonize plants during favorable conditions of temperature and moisture. From the study *P. aeruginosa* was recovered from 24% (14 out of 58) of the California soils tested.

The role of plasmid DNA in genetic material transfer particularly the transfer of antibiotic resistance genes among species of microorganism, humans and animals cannot be overemphasized. Studies have shown that plasmid DNA could be amplified from soil or clay particles (Cai et al., 2006, 2007, 2009; Tien et al., 1999; Zhou et al., 1996). According to Cai et al. (2007), polymerase chain reaction (PCR) was used to amplify plasmid DNA bound to soil colloidal particles from brown (Alfisol) and Red soil (Ultisol), and three different minerals (goethite, kaolinite, montmorillonite). The ease of isolation was dependent on the particle type. The cosmetic use and consumption of soils or clays which contain antibiotic resistance plasmid may be of grave adverse effects to humans. This may significantly contribute to the problem of emerging antibiotic resistance.

Also of important microbiological consideration is the association and survival of prions in soil. Prions are incriminated in transmissible spongiform encephalopathies (TSEs) in humans and animals, primarily affecting the central nervous system (Prusiner, 1998). Kuru provides the principal experience of epidemic human prion disease giving rise to the onset of variant Creutzfeldt-Jakob disease (vCJD) (Caughey, 2003; Collinge et al., 2006). Its incidence has steadily fallen after the abrupt cessation of its route of transmission (endocannibalism) in Papua New Guinea in the 1950s. Johnson et al. (2006) examined the potentials for soil to serve as a TSE reservoir by studying the interaction of the disease associated prion protein with common soil minerals. The study demonstrated substantial prion protein adsorption to two clay minerals, quartz, and four whole soil samples. Despite cleavage and avid binding, prion protein bound to montmorillonite, remained infectious. From the study it was suggested that prion protein released into soil environments may be preserved in a bioavailable form, perpetuating prion disease epizootics and exposing other species including humans to the infectious agent.

The act of processing clay-rich soil for consumption by heat treatment or baking may probably render the soil safe of pathogens, however, the effectiveness of the processing remains a question to be unraveled. This will depend on the type of microorganism present as spore-formers tend to be resistant to heat treatment. In an experiment conducted by Pedersen and co-worker (2000) where by bentonite was exposed to low (20 - 30°C) and high (50-70°C) temperatures, the spore-forming *Desulfotomaculum nigrificans* and *B. subtilis* were the only surviving bacteria. However some schools of thought are of the opinion that too much processing may reduce the clay's therapeutic potential. For instance, a comparative study of 'pharmaceutical grade clay' versus 'the natural and commercial herbalist clay by Mascolo et al. (1999) showed an appreciable depletion of trace elements in pharmaceutical grade clay.

## INDIRECT EXPOSURES TO SOIL AND SOIL CONSTITUENTS

Some indirect consumption of soil or its components may also be of grave consequence to human. Nitrate runoff and leaching from soil can lead to nutrient enrichment of water bodies and result in eutrophication which in turn will lead to algal bloom in which toxic cyanobacteria (blue-green algae) species dominating phytoplankton blooms (Carpenter et al., 1998, 2008; Glibert, 2007; Horrigan et al., 2002). Cyanobacterial toxins can cause a variety of human illnesses including gastroenteritis, atypical pneumonia, allergic and irritation reactions and liver diseases including cancer (Bell and Todd, 1996).

The deposition of faeces from human and other animal sources onto soils can potentially infect water supplies with bacteria, protozoa (*Cryptosporidium, Giardia*) and viruses (Rose, 1990). *E. coli* can remain viable for several months in soil, although there is scarcity of data on the behaviour of the pathogen in different soil types. Whilst most common causes of *E. coli* 0157-related poisoning have been associated with the consumption of contaminated meat and dairy products, there is also evidence that human infection has occurred through the ingestion of, amongst other things, contaminated soil and drinking water (Abrahams, 2002). Cattle are the primary reservoir of this bacterium, and consequently there are serious implications for the land-based disposal of cattle manure and slurry and abattoir waste.

There has been evidence of transfer or antibiotic resistance bacterial genes into the environment (Chee-Sanford et al., 2001). Animal feeds are supplemented routinely with antibiotics such as tetracycline for growth and diseases prevention (NOAH, 2001). Furthermore, the study by Chee-Sanford et al. (2001), on the analysis of samples from farm waste lagoons and nearby ground-water reservoirs revealed that bacteria in the soil and groundwater carried tetracycline resistance genes that were almost identical to those in bacteria living in the animals' guts. Hence, the occurrence of antibiotic resistance genes in groundwater provides a possible way for humans to acquire antibiotic-resistant infections. The study strongly suggests that the animal bacteria are transferring their genes into other ecosystems.

## HUMAN GEOPHAGIC PRACTICE: GENERAL HEALTH CONSIDERATIONS

Issues around geophagia are conflicting while some beneficial roles have been described for this form of pica, others have found it detrimental and an aberrant behaviour. Klein et al. (2008) alluded to the hypothesis that soil enhances the pharmacological properties of the bioavailable gastric fraction. In other words, it enhances bioactivities. Highly adsorbent smectitic clays have been demonstrated to cause the lining of the vertebrate gut to change both on a cellular and acellular level, potentially protecting the gut from unwanted chemicals as well as alleviating ailments such as esophagitis, gastritis, and colitis. According to Johns and Duquette (1991), humans use clay explicitly to render tanniniferous acorns and alkaloid-rich potatoes edible.

The benefits accruing from soil is unquantifiable. Abrahams (1999) highlights the fact that geophagia provides for a direct soil-human geochemical pathway given that ingested soils have the potential to supply important elements such as iron (Fe) to an individual (Smith et al., 2000). There could be some economic advantage accruing from the practice of geophagia. Vermeer and Ferrell (1985) revealed that a single Nigerian village produces 500 tons of soil yearly for consumption across West Africa; hence geophagia is a source of income generation. To date, scavenging for geophagic material still persists and forms a source of income to most rural dwellers involved. Trade in geophagic material as thera-peutics serves a means of income (Shirleys Wellness Café, 1996).

## CONCLUSION

Geophagia is a result of an interwoven multivariate factors ranging from cultural to religious and even disorders. The microbiology of soil and clay is a very broad in-exhaustible science. Millions of soil microbes are yet to be isolated and identified; hence their activities and the product they release into soil are not fully known. A few of the soil microorganisms which have been identified have demonstrated ability to impact on soil quality and its component through their metabolic activities. The microbes maintain decomposition, mineralization, nitrogen cycling, storage and release of nutrients, carbon cycling, and take pollutants out of the water before it reaches underground or surface water. Research is needed to identify and quantify reliable biological or ecological indicators of soil quality. Beneficial as well as several hazards have reportedly been based on consumption of soil. Whether the benefits of geophagia outweigh the harmful effect and vice versa remain an unresolved issue which warrants further investigation.

The intricacy of the microbiological aspects of geophagia makes it a fascinating area of study. A lot needs to be unraveled in terms of the soil, constituents, human consumption and health. The interplay of factors involved in geophagia, though varied, intricate and researched, may not have been fully elucidated. This review is expected to stimulate interest in this area of significance and in particular the emerging microbiological issues surrounding geophagia. Future studies will be geared towards profiling microbial content of soil consumed and those from stool samples of geophagic people. The relatedness of the pathotypes will be explored by phylo-genetic analysis. Further concerted efforts aimed at multidisciplinary research are warranted so as to address gaps in the corpus of knowledge on the important subjects.

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