Chapter 22
Do Pedo-Epidemiological Systems Exist?

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22.1 Introduction

Human health is a field for specialists but also a universal concern. The increase in information and analysis in the various kinds of media make it possible for every one to form an opinion, right or wrong, on the health hazards that we will incur. In parallel, progress on experimental and investigative techniques, and dramatic increases in the masses of knowledge in the biological and medical disciplines has lead to an increasing splitting of research, to the detriment of the understanding on the overall pathogenic systems. This double situation very often leads to a division of simple relations between risk factors and medical impact, largely subdivided by disciplinary approaches The reality is that the emergence and/or the space-time variability of health hazards can be seldom expressed in simple relations of cause and effect.

In France, during the period 1970–1980, H. Picheral, health geography Professor at the Montpellier University forged a new concept—the pathogenic system. For him, disease is the result of multiple interactions and reveals the physical and social structure of space (Picheral 1983). The initial object of research in health geography is thus the spatial, social and temporal variability of the disease and its factors—something that it has in common with epidemiology. But the final objective is to understand how the spatial heterogeneity of disease risk came into being, and how pathogenic systems function. Picheral distinguished four principal pathogenic systems:

- the eco-pathogenic system (where the environment plays an important role; *e.g.*, African Human Trypanosomiasis and vegetation),
- the techno-pathogenic system (where technical and industrial development dominates in the explanation of the risk; *e.g.*, cancer and dioxins),

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E.R. Landa and C. Feller (eds.), *Soil and Culture*,
DOI 10.1007/978-90-481-2960-7_22,

- the socio-pathogenic system (dominated by behaviour; e.g., alcoholism), and
- the genetical pathogenic system (*e.g.*, haemophilia).

The questions forming the framework of this article are thus:

- Within the large pathogenic system groups, can one identify pedo-epidemiologic systems dominated by the role of the soils in the explanation of health hazard variability, or at least in which the soils have a considerable role?
- Do pedo-epidemiologic systems exist whose impact can be reduced or thwarted by a preventive or curative action on the soils?

22.2 Soils and Exposure to the Health Hazards: a Brief Survey

Many publications have surveyed the relation between soils and health (Oliver 1997; Abrahams 2002; Sanchez 2002; De Silva 2003; Brooker 2006; Lal 2007).

Thus, the soil can be perceived as a mixture of components some of whose elements are potentially toxic for the man by inhalation, ingestion, or direct contact. Radon, lead, chromium, aluminum, arsenic, cadmium, and mercury are frequently evoked. Although the potential toxicity of the elements mentioned is not questioned, a sharp debate exists between experts to determine the thresholds and the acceptable concentrations in human and animal health (Glorennec 2005) (see Chapter 21 by Steinnes, *this volume*). In such discussion, these thresholds should be based on pedological conditions. The acidity of the soils, for example, is a crucial factor of insolubilization or availability of trace elements and aluminum (*e.g.*, Cambier 1994). In this case, the soil plays an active role in the relation between man and health.

In other cases, its role is passive. The soil is then a simple material support. It can be the medium in which parasites live; the pathway of exposure may be ingestion of soil adhering to food in the case of many intestinal parasitic diseases (Oliver 1997), or direct contact between the skin and the contaminated soil, as in the case of myiasis (Zumpt 1965). Myiasis is a class of diseases related to the parasitic development of dipterous larvae in living tissues (or in some cases, on the wounds of animals). Others are parasites of natural openings such as the nostrils, or of digestive tract. In the case of the Cayor worm (*Cordylobia anthropophaga)*, the fly lays eggs on wet ground or wet clothing, and the larva passes to the skin that comes into contact with this substrate. The larva develop in the skin before transformation into the adult fly. Myiasis is frequent in the tropical zone ("Cayor" is the name of a Senegalese district along the Atlantic coast) and affects the humans as well as other animals (Devienne 2004)). Most often, it needs wet, sandy soils.

The larbish or creeping disease is another example of risk related to a direct contact between the skin and contaminated ground. It can also be the medium of transmission of the bacteria causing tetanus (*Clostridium tetani*) that can invade the body when soil is introduced with puncture wounds (Sutter 1998)—introduction here by soil adhering to the larva.

Larbish (Chabasse 1995) is a "cutaneous larva migrans" syndrome (also called "creeping eruption"), caused by the active penetration of human skin by the larval stage of a parasitic organism shed by a lower-order animal. Most often, the species involved in this syndrome are larva of nematodes (*Ancylostoma braziliense* or *Ancylostom braziliense* in most tropical and sub-tropical countries, *A. ceylanicum* in south-east Asia, and *Uncinaria stenocephala* in temperate climate regions). These parasites are common in the digestive system of cats and dogs. The parasite eggs will be released in the environment with the stools of these animals. If they encounter sandy and shaded soils, and if temperature and humidity are high, eggs will then hatch out and contamination will be possible. Human contamination will appear with a simple direct contact between skin and soil contaminated with animal stools. But it is a specific animal disease and in the case of human beings, the parasite can't develop for a complete cycle. So the larva cannot leave the skin and will cause the symptoms of larbish—a red, raised network of tunnels on the surface of the skin caused by the burrowing of larva. Hands, feet and buttocks are most commonly affected, and severe itching is symptomatic of the condition. The area of distribution of this disease is mainly the tropical subtropical area, and in particular, the coastal regions because of higher degree of humidity. One of the authors was infected by larbish while studying podzols on the coastal region of the Republic of the Congo (Congo Brazzaville).

Soil can also serve as a reservoir for other bacteria waiting for a receiving host that will be at the origin of a cycle of transmission. Thus is evoked the possibility of the inter-epidemic maintenance of plague ("black death") thanks to the survival of the causative bacterium *Yersinia pestis* in certain soils (Karimi 1963; Drancourt et al. 2006). Rats and mice, the natural hosts of the plague, are susceptible to the disease and their populations are decimated by it at the time of the epidemic events. So one of the crucial questions for public health specialists is how the bacillus population is maintained in the environment, apart from any reintroduction. Laboratory studies suggest that the bacillus can survive in the soil for long periods, but this has yet to be demonstrated in the environment. A digging animal, such as a rodent, could then exhume the bacillus and contaminate itself. In another digging scenario, soil particles can be dispersed as an aerosol, causing a plague outbreak.

Soils can also play important roles in other vector-transmitted diseases. Thus, *Glossina palpalis*, the TseTse fly responsible for the transmission of the African human trypanosomiasis in West Africa, develops starting from an egg deposited by an adult in the soil. The soil is the essential medium to the maintenance of the epidemiologic chain (Laveissiére et al. 2000). In the forest, the favourable soils for TseTse larvae are typically black soils, high in organic matter. High clay content and very wet conditions are unfavorable environmental conditions for the larva because they permit development of predators such as termites (clay soils) or fungi (wet conditions).

In Western Africa, the causative agent of sleeping sickness is *Trypanosoma brucei gambiense (T. rhodesiense in East Africa)*, a protozoan reproducing in the blood of the human host. The introduction of only one parasite into a man can lead to death in a few years, even a few months. Humans can be infected with this protozoan by the bite of the TseTse fly (*Glossina* spp.). In West Africa, only *Glossina palpalis* and *Glossina tuchinoïdes* are vectors of sleeping sickness. The TseTse fly is exclusively African, occurring between the 15° northern degree of latitude and the 20° parallel south. These insects need a shady and wet environment to live, and not too high temperature (forests, cocoa or coffee crops in Sudanese areas; all botanical types in forest areas, with a preference for the skirts of forest and villages, as well as shady water spots). The only recognized reservoir of the parasite is man.

At another level, mechanical properties of soils can also be important. Windborne soil particles can play an important role in the processes leading to infectious diseases in humans. In West Africa, the incidence of meningitis, caused by the bacterium *Neisseria meningitides* (Lapeyssonie 1963), and ocular affections such as keratitis and trachoma (Schemann 2007; Reinhards J 1970) are linked to the Harmattan, the dry and dusty West African trade wind that blows from the Sahara south to the Gulf of Guinea from December to March. The geographical location (a Sahelian and Sudanian belt) of these diseases can be explained by the role of the wind and the sandy soils, whose combined effect causes physical damage to mucous tissues, facilitating infection with these pathogenic agents. Sandy soils play here only a mechanical role, causing microscopic wounds. But the main risk factors are not linked to soils characteristics, but to social conditions, in particular water availability and hygiene practices.

Trachoma is the leading avoidable cause of blindness in the world. It is a *keratoconjunctivitis* (inflammation of the cornea and conjunctiva) due to an infection by *Chlamydia trachomatis*. The infection and irritation associated with it can evolve to *trichiasis* (ingrown eyelashes) in the second stage of this disease, causing corneal wounds that lead to blindness. The disease affects an estimated 84 million people worldwide; 6 to 7 million are at the ultimate stage, and 1 to 3 million are completely blind (Wright et al. 2008). The disease-causing agent is transported mechanically by flies, which mass around the eyes, thus making the infection possible.

We have focused above on infectious diseases. But clearly soil fertility is another key issue, with its clear link to crop yields and malnutrition (see chapter 21 by Steinnes, *this volume*).

Soil ingestion is developed in another chapter (see chapter 23 by Abrahams, *this volume*), but we note that soil consumption is at the heart of many cultural practices, including the ingestion of soils for therapeutic, magic or religious reasons (Young et al. 2007). But in the recent food crisis in Haiti (*Newspaper le Monde*, "A main food crisis will come" by F. Lemaître, 02 August 2008 edition), it was sad to see clay soil used as a "normal" food ingredient, the poorest people mixing it with a small quantity of corn or wheat flour for preparing a kind of bread.

Clays are widely used by the pharmaceutical and the cosmetics industries. They have been used for a long time to allegedly prevent the ageing of the skin and the development of wrinkles. Masseurs use hot mud plasters for cosmetic and therapeutic purposes. Indeed, recent studies at Arizona State University showed that some non-soil clays had antibacterial properties. A clay from the French Massif Central has been used successfully against the MRSA [methicillin-resistant *Staphylococcus aureus*] (Williams 2007). But limiting the soil-related health hazards only to these direct relationships would reduce the complexity of the question and limit many actions in terms of prevention and combating disease. In the case of onchocerciasis ("river blindness"), the medical impact of the soils is indirect but nevertheless insidious.

Onchocerciasis is a parasitic disease in humans, associated with the nematode *Onchocerca volvulus*, The larva of *O. volvulus* can invade the eyes causing serious and irreversible ocular disorders whose ultimate stage is blindness. The vector of this parasitic disease is a small biting midge (black fly) of the *simuliidae* family. At the time a blood meal is taken on a sick person, the female introduces larvae of which some (after migration and changes in the midge's body) will gain again the oral parts. At the time of a later blood meal, these larvae will then be inoculated into another person. These parasite larvae will then transform into adults able to produce millions of new larvae, the pathogenic stage of the parasite. The stage of the parasite in the vector is essential. The distribution of this cumulative effect is thus dependent on that of the vectors. They develop only in rivers where an acceleration of the current produces a greater water oxygenation, essential to the development of the midge's larvae. These places of reproduction can thus be easily localized, facilitating the fight against the vector.

Onchocerciasis is a parasitic disease in humans. A key component of the disease cycle is the black fly, which by successive bites transmits the parasitic worm *Onchocerca volvulus* from infected persons to healthy persons. In this disease, the gravity of the symptoms depends directly on the number of infecting punctures received by a person per day. This index varies according to the vectorial density (*i.e.*, how many black flies are present) and from the conditions of man/vector contact. For its larval development, the fly needs well-oxygenated water, available in particular in the rapids of the great Sudanese rivers; nations in Africa where the disease is prevalent include Burkina Faso, Mali, Ghana, Guinea Konakry, Ivory Coast, and Sudan. This ecological requirement makes the river valleys of the region places of high risk for river blindness. However in this bioclimatic zone, these valleys have the most fertile soils, inevitably attracting the farmers and their families to a vector-rich environment. So rich soils play an indirect role in that disease by attracting populations to high-risk areas (Hervouët and Prost 1979). One could multiply the examples, but the objective is not so much to draw up a list of all possible risks, but to evaluate the weight that the soil component takes in some of the pathogenic systems mentioned above.

22.3 Soil and Pathogenic System

Following H. Picheral (1983) and his pathogenic system, disease is not just cause and effect, but rather is a complex system with multiple interacting factors and the possibility of feedback loops. According to this concept, that underlies most current studies of health geography in the French-speaking scientific sphere, soils can be understood only as one contributing element of the whole. Let us take the example of a hypothetical pedologist…

Consider the case of pedologist Professor Pierre Solterre who traverses the world in order to enrich his knowledge of the structure and function of certain types of soils for which he is a recognized authority. Using a spade, Professor Solterre starts to dig a pit in order to examine the soil profile. The spade hits a large tree root, which he cuts with a knife and removes by hand. He pricks himself slightly with a splinter while pulling out the root. Tetanus introduced silently on this occasion begins its work, without Professor Solterre noticing any symptoms. Continuing his work, soil starts to stick to his hands and feet, and larbish settles, ready to draw a pretty reddish network under the skin that will itch during long weeks. Engrossed in his work, he does not see the centipede that stings him and injects its venom. The sting is painful and he flails his arms, striking the powdery and unstable walls of the pit—the collapse of one wall sends up a cloud of dust that makes him cough. Rubbing his mouth with his dirty hands, the Professor swallows, without realizing it, perhaps 100 eggs of parasitic worms (helminths) that will hatch and continue their life cycle in his body. The mishaps of our dear Professor Solterre will not, however, prove fatal for him. Indeed, before leaving on his mission, Professor Solterre had the good idea to renew his tetanus vaccination. Moreover, his financial means has enabled him to assemble a large, expert team who could extract him from the crumbling pit. Lastly, on his return to France, he could consult a physician specializing in tropical medicine to treat his larbish and helminths.

This caricature illustrates some of the health hazards faced by an individual in his/her contacts with the soil. It also shows that the exposure will result in a pathological condition only under particular circumstances, and not according to an immediate and obligatory relation of cause and effect. One of the frequent practices in the analysis of the health hazards is to isolate an element from the system to which it belongs and to seek correlations, even causalities, by neglecting the whole system, as well as the interactions and feedbacks which affect it. Rather than adopt this approach, we will analyze the links within a given soil-related pathogenic system, and look for places where it may be possible to decrease the health hazard.

If one again examines the example of Professor Solterre, the health hazards related to the soil depends on several elements that lead to the expression of the disease:

(1) initially, the nature of the soil and its capacity to contain infectious, parasitic or toxic agents,
(2) then, the contact between the human and this soil by pathways and frequencies which make the exposure possible, and
(3) finally, the ability of public health measures to reduce or prevent negative health effects.

According to specificities of each one of these three mitigating factors, the health hazard will be expressed differently within the population, in space and in time.

Ascariasis afflicts hundreds of million individuals in the world. It represents an emblematic example of the soil-related diseases because of the ecology of the causative roundworm, which lives and reproduces in the soil. However, in their treatise *Medical Geography*, Meade and Earickson (2000) show that the variations of the exposure are due, as much if not more, to the cultural environment, than to the physical environment. Indeed, if the cycle of infection is dependent on an essential stage in the soil for the worm, the human contamination will not be homogeneous because of different life styles in the same space. Within a given community, not all individuals will be infected in the same way and same intensity. Controlling variables with respect to infection include facilities and practices for disposal of human wastes, dietary habits, type of flooring in homes, vegetation cover around homes, and soil wetness. The nature of the soils is only one, and not the dominant factor, in determining the risk of exposure to the Ascaris worm.

Research work conducted in the city of Pikine, a vast suburb of Dakar, Senegal, showed the heterogeneity of the incidence in the population of three important parasitic diseases—Giardia, Ankylostomiasis (hookorm infection), and Ascariasis—on the scale of the city (Salem 1998).

Giardia is a protozoan parasitic disease. Three species exist but only *G. lamblia* infect humans (Heresi 2000). It causes diarrhea and interferes with the absorption of fat from the intestine (malabsorption). The contamination of the soil is due to a form of the parasite—cysts—contained in stools. They can remain for a long time in humid soils, and for 2–3 month in fresh water. Human infection occurs by ingestion of cysts, associated with poor sanitation and hygiene.

Hookworm infection is due to parasites from the genera *Necator* and *Ancylostoma* that colonize the upper part of the human small intestine. These soil-transmitted helminth infections are widely distributed throughout the tropics and subtropics. Climate is an important determinant of transmission of these infections, with adequate moisture and warm temperature essential for larval development in the soil. Equally important determinants are poverty, inadequate water supplies, and sanitation. In such conditions, a variety of pathogenic soil-transmitted helminthic species may be present in a given patch of soil (Bethony et al. 2006). Soil is contaminated with eggs of the parasites excreted in stools, associated with poor sanitary conditions. Human infection will occur by ingestion of contaminated soils.

This variability, noted by studies undertaken in population samples from several districts of the city, showed that population densities, availability of utility services (such as roads, and water-supply/wastewater systems) appear to correlate with disease incidence The proximity of the Atlantic Ocean and resultant higher rainfall helps to explain the greater prevalence of these parasitic diseases compared to the African cities of the interior of the continent, but not the internal variability in the city of Pikine. On the other hand, this coastal location and the presence of a high ground-water table maintains moisture in the sandy soils, facilitating the persistence of the parasites in soil, ditches and other shallow bodies of water. Many authors (*e.g.*, Asaolu and Ofoezie 2003) underline the importance of education focused on health and sanitation in the control of parasitic diseases.

22.4 Urban Soil and Health

The city, across its demographic and functional characteristics, constitutes a medium where the visible soil is a secondary element of the landscapes. However by the lifestyles and the activities that characterize urban environments, these soils are subjected to intense contamination inputs. The soils receive an uninterrupted contribution of heavy metals resulting in particular from the domestic fuel combustion, motor vehicle traffic, waste incineration, power production and other industrial activities. The city of Turin, Italy (population ~1 million) was the subject of an investigation (Biasoli et al. 2006) whose conclusions illustrate this fact well. In this city of 133 km^2 (of which approximately 10% is covered by green areas), human activities contributed to a significant increase in the contents of lead, zinc and copper in the soil. In parallel, the pH of these soils is rising, thanks to the contribution of alkaline materials resulting from construction (*e.g.*, cinder blocks, concrete). This later phenomenon can then limit the assimilability of these heavy metals.

However, these phenomena should not be perceived as monolithic. A comparison between the towns of Turin, (Italy), Uppsala (Sweden), Seville (Spain), Ljubjana (Slovenia), Glasgow (Scotland) and Aveiro (Portugal) in connection with the mercury content of their soils allows the measurement of the contamination heterogeneity (Rodrigues et al. 2006). Mercury is a powerful neurotoxic agent, widely used in mining activities and gold extraction, activities mainly located in rural areas. But in urban/suburban areas, oil refining, coal combustion, industrial activities, waste combustion, use of pesticides, and use in batteries, medical devices, and electrical switches contribute to pollution by mercury. Through this study, the authors show a great variability of high levels of soil contamination on fine scales, about a few hundred meters, more than the variability between the six cities.

This heterogeneity of pollution is found, beyond the example of mercury, for many other contaminants. Thus, in the environs of Pueblo, Colorado, a town characterized by a long history of steel production and fabrication, arsenic, cadmium, mercury and lead concentrations in soil are higher than the national average (Diawara et al. 2006). In the inner city area, the authors show that areas inhabited by low-income, predominantly Hispanic and African-America people, are often characterized by the highest levels of pollution. So in their conclusions, the authors affirm that exposure to pollutants becomes an element to discuss in an approach to public health taking into account environmental justice. Depending on social behaviour and socio-economical level, children are exposed differently to lead contained in the indoor and outdoor environments (Laidlaw et al. 2005). Soil moisture appears to be an important contributing factor. In the urban areas where airborne dust is prevalent, people are more exposed to lead contamination.

Local characteristics that influence the presence of pollutants in soils make it possible to identify sites whose proximity will generate a risk for the bordering populations. For example pollution will act in different ways according to social conditions, human activities, soil characteristics and so on. The problem will then consist in identifying the areas of special concern with respect to these risks. This difficult analysis, taking in account the systemic dimension of the exposure to pollutants, is seldom chosen. On the other hand, analysis of polluting emissions and their impact on the surrounding soils is the subject of many studies, with an aim of either reducing or eliminating the source of pollution. In Barcelona, soil contamination by a solid waste incineration unit was the subject of a monitoring study whose results showed the weak risk for the surrounding population (Schuhmacher et al. 1997). In Newcastle, England, the analyses of soils showed that the spaces located under the dominant winds from the solid waste incineration unit did not coincide with an increase of heavy metals and arsenic content because of the background noise left by the industrial activities which followed one after another in the city since the 19th century (Rimmer et al. 2005). On the other hand, composted urban organic may represent a risk to public health. Close to Seville, Spain, experimental parcels of land receiving such urban composts showed slow accumulation of zinc and lead, and possible risk to humans consuming agricultural products grown on them (Madrid et al. 2006). The authors suggested the need for lowering the thresholds of toxicity considered to be acceptable by the Spanish government. In these systems, where human activities lead not only to pollution of soils but also to production of soil amendments by transformation of wastes, regulatory controls on multiple fronts becomes important tools for protecting public health. With a view to sustainable development, public authorities can control the risk by adequate measures (Mohan 2006) based on available techniques. For that to occur, it is still necessary that a clearly stated policy and adequate procedures exist (Nathanail 2006).

It is thus valuable in these artificial situations [such as cases where residues produced by urban/industrial activities (as opposed to traditional organic composts produced by natural transformations of biomass) are added to soils as amendments in urban/suburban agriculture] that one is able to identify potentially significant pathogenic pathways contributing to soil contamination, and to assess human exposure from contact with and usage of such contaminated soil. These health-risk situations are the basis of the "pedo-epidemiological systems" we are trying to identify.

22.5 Health of the Soil for a Health of the Man

The analogy between the health of the soils and human health is very old. The reasons are varied: perception of the soil being like a living being, the will to control human health leading to a desire for healthy management of soils, or simple ignorance of the soil processes. Thus, agronomists of past times understood that certain substances improved qualities of the soils. These "manures" were perceived more like drugs than like food (Boulaine 1989). One will notice that in French, the term "engrais" (fertilizer) has the same root as "engraisser" (to fatten). So fertilizer will fatten the soil. A sign of opulence certainly, but probably also an allusion to the fatty and smooth feel of soils rich in fine-mineral matter (clay- and silt- size fractions) and organic matter, recognized as being very fertile by experiment. In certain cases, the analogy goes very far. Thus, in biodynamical agriculture, created by the philosopher Rudolf Steiner (1924), substances are given to a soil in homeopathic amounts, at certain very precise moments (*e.g.*, full moon) to cure it. This approach, very empirical, is eminently anthropocentric.

But it has its limits. Thus, a soil low in trace elements, or in which these elements are poorly available (due to high pH or other factors), will induce deficiencies in the plants which grow them, then in the fauna which take nourishment from these plants, and in the humans living off its native and cultivated vegetation. This is the case, for example, of tropical arenosols (weakly developed sandy soils—*e.g.*, recent dune sand, beach sand). Can one say that the soil is sick? A more rational approach consists of saying that the soil is deficient. Rather than looking at the soils as sick bodies, the scientific approaches prefer to regard them as non-renewable, fragile resources, to be preserved with a view towards sustainable development.

22.6 Can One Connect Soil Types and Health Hazards?

So to the question posed in the title: Can one connect soil types (within the meaning of pedological classification) and health hazards? In certain cases, clearly not: for example, soils can be a simple physical support of varied parasites; even if some physical or chemical characteristics such as particle size distribution, moisture content and pH may influence the presence and the abundance of the parasite, it is seldom possible to correlate these characteristics with a precise type of soil. In other cases, the relationship seems more direct. Thus, a bond exists between hydromorphic soils [soils that are developed in the presence of excess water (all or part of the time)] and various medical problems—transmission of diseases such as malaria and schistosomiasis, the presence of molds, aggravation of rheumatism in damp conditions, and vulnerability to floods. But the correlations are not causal. In fact, as the flood case clearly exemplifies, it is the hydrological cycle, rather than the hydromorphic soils, which is truly at the root of the medical problems.

Another example is related to the landslides. Contrary to other geomorphological and geological risks, such as earthquakes or floods, landslides have a formal pedological component. Although such phenomena can happen in many movable, thick materials, and can be triggered by heavy rainfalls, they are particularly frequent in the ferralitic soils (also known as oxisols in the USDA soil taxonomy or ferralsols in the FAO classification) in wet intertropical areas. Two factors play a central role here: (I) the type of soil—several meters thick and covering movable unconsolidated material (regolith) up to several tens of meters thick, and (II) a particularly wet climate. A third factor is added to it—strong relief. These three factors are not independent. The hot and wet climate has a fundamental role on the thickness of the regolith; the mountainous character accentuates climatic moisture; the relief is accentuated by the nature and the thickness of the regolith, which is more sensitive to geological erosion than unaltered parent rocks. In short, the relationship between landslides and the health hazards associated with them on one hand, and soils of the other hand, is only partial. It is the whole of the environment that has to to be taken into account

22.7 Conclusions

Whether one approaches the relationship of soils and health from one end of the spyglass or the other, it appears obvious that the image can be only be valuable if these terms are put in the perspective of the total environment. This systemic approach that we advocate here, strives to be operational by identifying the causal elements on which it will be possible to act and thereby improve health outcomes. This approach also makes it possible to analyse, in a more realistic way, the concept of risk compared to the total scope of factors influencing health. Thus, in current discussions of global warming, one often sees mention of the medical question, in general, and the evolution of the endemic areas of tropical diseases, in particular (see for example, the "deadly dozen" list of pathogens that may spread as a result of changing temperatures and precipitation levels that was released in 2008 by the Wildlife Conservation Society—including intestinal & external parasites and sleeping sickness—available at http://www.wcs.org/deadly-dozen/wcs_deadly_dozen). To take the example of malaria and its possible return in the countries of the Northern hemisphere, it is thus advisable to remember the factors that were responsible for its disappearance in Europe. Indeed, soil management practices—in particular drainage of large tracts of hydromorphic soils, and limestone amendments on acid soils (making it possible to improve soil structure and increase permeability), eliminated favourable sites for vector development (Fanica, 2006) —namely mosquito-breeding areas. The action of man on the soils, and the management of the environment towards improved habitability and agricultural productivity by human societies made it possible to improve the sanitary situation by eliminating the vector.

Soils must thus be taken into account as one of the elements of environmental systems where active management may lead to positive health outcomes. So, if it is evident that soils play an important role, and we cannot talk about pedo-epidemiogenic system for most of the diseases or syndromes evoked in this paper. Human infection by parasites is more the result of life style, social behaviour, hygiene, and environmental management than of soil characteristics. Indeed, even if the soils constitute a necessary substrate for certain parasite life-stages, human infection is not inescapable and varies according to the types of populations which live in the contaminated zones. The use of composts produced with urban wastes could be considered a contrasting case. Here, contamination of environment with heavy metals or urban waste residues is the direct consequence of a process based on soil amendment. In this case, preventive actions can assure that such amendments will not degrade soil quality This case represents a sub-category of Picheral's techno-pathogenic system.

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Do pedo-epidemiological systems exist ?

In : Landa E.R. (ed.), Feller Christian (ed.), Descola P. (préf.). Soil and culture.

Dordrecht : Springer, 2010, p. 355-368.

ISBN 978-90-481-2959-1