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Review Article

Necroleachate and Public Health

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Abstract

This paper covers the relevance of necroleachate in cemeteries. Throughout history and nowadays the construction of cemeteries has always been a controversy. Such places are deemed as contaminants due to decomposition of natural bodies inappropriately buried, causing the spread of pathogenic microorganisms and environmental impact. However, the concern about the environmental issue in places occupied by cemeteries began in the midst of past century, and recently a great concern about the environment increased. Thus, environmental agencies made some resolutions to prevent that cemeteries become polluting agents, allowing them to operate only after a suitable environmental licensing. In view of this problem, analyses determined that necroleachate is gradually eliminated after burial, and it can reach the groundwater with the action of rainwater and contact with surface waters, bringing negative consequences since its matter causes potential damages to the environment and public health. When necroleachate pollutes the groundwater, we note that it puts at risk both the environment and citizens using ground watershed that can be contaminated by virtue of bacteria, virus, and protozoa. With the aim of environmental quality, it is necessary to apply necroleachate-treatment methods in order to turn it less toxic and pathogenic.

This study was the basis of inspection for the Environmental Police of Rio de Janeiro, when the police commanders carried out forensic operations with their teams and they found glaring environmental crimes in all operations.

The practice of the environmental police was facilitated by this study when they influenced Municipal and State administrators to comply with the current environmental legislation, reducing impacts on the environment.

As uppermost point, the study was the basis of regional and national news about the criminal status of some municipal cemeteries, bringing the civil liability to governmental authorities.

Keywords: Necroleachate; Public Health; Perimeter

The Hebrews had the habit of separating a place for burial as cited by several history sources, action improved by Christians with the creation of catacombs in ground gallerywalls.

The ancient Rome prohibited the burials within the city, resulting in burials along the road. However, along with growth and development of cities, the deceased buried in far places returned to theurban perimeter.

History

Originally, the cemetery was a place of death sleep. Then, in recent centuries, the word 'cemetery' gained the meaning of necropolis, campo santo, eternal home, etc.

Along several scripts, the Bible names cemetery as the place where the deceased sleep until they are awakened by the hornets of the Last Judgment when they will arise incorrupt. Sometimes, death is a synonym ofsleep, as in the case of Jesus when he told about

Lazarus's death: "Our friend Lazarus has fallen asleep; but I go, so that I may awaken him out of sleep" (John 11:11) - King James Bible. However, death is not always meant to be this way in the Bible. Death is deemed as the human disgrace in the Old Testament.

When Romans prohibited the burials inside the city, they were not concerned with the organization of cemeteries. Thus, tumultuous burials arose along the roads, not only because such locations had easy access, but mainly due to the constant remembrance of deceased, thanks to bystanders, at least temporarily.

As cities developed, suburban sepultures became partially urban, in other words, deceased ones that have been removed from the city were present again. They have been like this until our days.

As a set of graves or tombs, it is probably that cemeteries hade began as long as humans remained in certain regions, and also with the commencement of private properties.

The Roman Law of Twelve Tables in the year 303 prohibited the burial of deceased ones in the city. As a result, Romans began the construction of tombs either in the villages (country houses) or at the brink of public roads.

The prohibition lasted until 820 with the decree of the Byzantine Emperor Leo VI, the Wise, in his Novel 53, when he authorized burials inside and outside the city. Similarly, to the increase of cities and inhabitants, the permission resulted in agglomeration of tombs around churches.

The Christian cemeteries were other type of cemeteries that started to appear far from the cities. According to Tertullian, their construction began in the end of II Century. As per law, cemeteries need to be located outside the city, underground, or at free spaces, but surrounded by walls or columns. Due to persecution of Christians, cemeteries became a suitable place for meetings and prayers.

The cemetery in the middle ages

During the historical development of cemeteries, the middle ages are worth of attention. At those times, the cemeteries were not deemed only as the place of burial, but they were the center of social life, as the church.

In the Middle Age and during the XVII Century, it corresponded both to the idea of public square and to the current idea, exclusive for burial services. The word had two meanings from only one that was replaced since XVII Century until nowadays.

At that time, cemeteries virtually stopped to be the place of deceased to become the refuge of the living ones. The refugees that were firstly and temporarily located in the cemeteries, now remained definitively there, doing constructions and living normally.

There were legal issues and, in the XII Century, an ecclesiastic court granted permission to feudal lords charge census from the cemetery inhabitants.

The cemeteries stopped to be a place for peace and tranquility in the beginning and became a place of noise, trade, because everyone there wanted to make social and commercial relations. There were processions, civil and military courtships and even justice, in other words, generally adjudication of State in the cemeteries. In the XV Century, Joan of Arc was judged by a court in the cemetery of Saint-Ouen, in Rouen.

Near the XVII Century, the cities was full of deceased, this is, and the cemeteries were notable in the urban environment. A new concern appeared with public health along with additional cares with burials, and more dignity in cemetery maintenance.

The local accumulation of deceased in the churches or its courtyards became intolerable several times, at least to the scholarly at that time, such as the abbot Porée.

In the XVII Century, a concern to separate the cemetery from church was verified by the Church, even due to demographic needs.

This was the first step to withdraw cemeteries from the cities. The stink was now removed.

The premises of public hygiene began near the year 1780, and then cemeteries are the first spaces reached, at one-step to attain a remodeling of urban space.

The phase is initiated with the Decree of June 12, 1804 in France, dictating the rules we still see today.

It definitively affirms the prohibition to bury in churches and cities, and that burials become far apart, at least 35-40 meters from the urban perimeter. It determines that bodies are not overlaid anymore, but juxtaposed. The decree fixed a minimum distance between one grave and another, and it voided their reuse. The grants of everlasting graves appeared for the first time, in legal terms, being legally granted only to those who offered donations to the poor ones, regardless of the amount.

However, the deceased were in the city once again in short time. The problem was mainly due to the increase of deceased population, and the State is pressed to take measures in order to eliminate the stink coming from the cemeteries. The pioneer of this problem in Brazil was José Correa Picança in his paper "Ensaio sobre o Perigo das Sepulturas nas Cidades e nos seus Entornos (1812)", highlighting the historical approach of the issue.

Introduction

The word cemetery comes from the Greek "koimētérion" that means a place to sleep, but with Christianity the term had the meaning of a place to final postmortem rest, only for places where burial of deceased takes place (from the Latin cadāver –dead body).

The cemeteries can become a big source of social problems if they are not duly created and managed. Thus, this environment have to be designed taking into consideration mainly its physical location, including the type of soil, groundwater depth, and land tilting. In addition to physical factor, the social environment needs to have the same importance.

In the end of XVII Century, Europe created sanitary rules and started to make burials in open areas, the so- called campo santo or secularized cemeteries. This change reached especially the persons with political and religious influence that tried to preserve the tradition of burials in the churches. So far, the open spaces called cemeteries were reserved to "non-Catholic" persons (protestant, Jews, Muslim, slaves and condemned ones). However, they established a law that obliged all to be buried in sunny fields. The large concentration of bodies in vessels and church undercrofts leaded to a high rate of diseases transmitted through cadaveric decomposition (Langalde, 1990).

The quick urbanization and city growth were also important factors to create open collective cemeteries, since the unstoppable population growth prevented the burial in chapels and churches that could not bear the increase of demand.

The cemetery is a necessary enterprise to the society, but it has always been a matter of concern since it is a high-polluting environment with large psychological impact. Historically, the construction of a cemetery has always been a controversy. Even in current days, when a cemetery construction is proposed, the community itself becomes concerned and makes favorable or unfavorable manifestations, resulting in big tumults in the cities in general.

However, despite of inconvenience that a cemetery brings to social interaction, there is a psychological need to keep a material relationship between the alive ones and deceased. Thus, cemeteries are a need in the cities. In this sense, the city has the power to manage the public equipment, both municipal and private; it is the administrator of community well-being meeting the needs of population referring to burial activities, providing psychological comfort to the population.

Contamination due to necroleachate may cause serious sanitary and environmental issues. Therefore, even cemeteries established with all environmental protection measures may not be deemed as perfectly individual places to the environment. In all cases, the chance that liquid effluents are released outside cemeteries must be considered with constant monitoring of such works.

In this context, several aspects must be considered while designing and establishing a cemetery. Poor conservation or even unduly location of graves may lead to leakage of product and become contamination spots to the groundwater. Other ruling factor is the presence of large trees inside cemeteries. In this case, what could act as a benefit of visual and thermal comfort may cause big problems of groundwater and soil contamination due to roots causing the destruction of graves.

When the grave wall is broken, accordingly, it is easily flooded by rainwaters, and afterwards, these contaminated rainwaters enter into the soil, reaching the groundwater.

Some historical cases of groundwater contamination were recorded by Bower (1978 apud PACHECO, 1986), where the necroleachate (from the corpses) was found in the waters related to human usage. The author highlights the incidence of typhoid fever among people living near the city of Berlin, from 1863 to 1867 and the case in the city of Paris, where the smelly and sweet groundwater was captured in wells near cemeteries, especially during hot weather.

Thus, the concern with groundwater is relevant, since its contamination by such enterprise is a COLLETIVE health issue. Other point that entrepreneurs and the design team must take into consideration is that groundwater committal is extremely difficult and costly to revert.

Methodology

- This work applied knowledge of the Biology field.
- Among them, we highlight Environmental Contamination and Legislation, Soil Mechanics, Soil Quality, Sanitary Biology and Bioremediation.
- We carried out researches in monographs, thesis, scientific papers and sections of books to help in the theoretical basis; queries in national legislation related to cemetery environmental licensing.
- We used news and publications related to the matter.
- And finally, we carried out expert investigations in public cemeteries in the cities of Araruama, Iguabinha, and Búzios located in the State of Rio de Janeiro, Brazil, from 2018 to 2019, where the Expert Witness Mariane Malvão Fernandes, Biologist, was escorted by the Environmental Policy of the State of Rio de Janeiro during inspection operations as a Scientific and Technical Expert Witness.
- Observations of the current cemetery situation were carried out there, where we found several glaring criminal infringements.
- Unfortunately, we could not perform a more detailed geological and topographic study of the locations.

American environmental law

According to the legislation referred to environmental contamination, the most relevant environmental legislation in the American system can be chronologically organized as follows:

- **National Environmental Policy Act (NEPA):** Effective since 1970, establishing wide objectives to the national environmental policy and determines that federal agencies provide environmental impact assessments when the actions that can cause impacts are relevant.
- **Clean Air Act:** The amendments of 1970 Clean Air Act establish a set of federal regulations to control air pollution, and they replace the 1963 Clean Air Act. They provide a deadline pack to the EPA to enact air quality standards to be implemented by States and national standards for dangerous air pollutants. The citizen suit was also provided in the legislation so that every citizen has an air quality-procedural instrument. The law was amended in 1977 to require more restrictive controls in the regions that fail to comply with dangerous air pollutant national standards with the main objective to fight against the serious issue of acid rain. It had a new amendment in 1990 creating a new regulating modulation to verify the air quality.
- **Federal Water Pollution Control Act (Clean Water Act):** Approved in 1972, the law prohibits pollutant discharges in water surfaces; it requires the use of technology based on controls over discharges, establishing a national program, the National Pollutant Discharge Elimination System (NPDES), that must be implemented by the States subjected to EPA supervision. It authorizes aids and grants to construct sewage treatment plants, and it provides the citizen suit so that every citizen can promote the defense of water quality. The 1977 Clean Water Act Amendments and 1987 Water Quality Act significantly amended this Act.
- **Federal Insecticide, Fungicide and Rodenticide Act (FIFRA):** This Act related to pesticide control emended the 1947 legislation, and it required the registration of pesticides, in addition of authorizing the EPA to prohibit them if dangerous. The legislation was amended in 1988 to require a more efficient and regular review of pesticide records, and in 1996 with the approval of Food Quality Protection Act, it started to require a more stringent protection against pesticide residue on food.
- **Marine Protection, Research, and Sanctuaries Act of 1972 (Ocean Dumping Act):** Approved in 1972, this act prohibits the waste discharge in the ocean, except with the permit, and in places assigned by the EPA.
- **Endangered Species Act (ESA):** Approved In 1973, this legislation prohibits federal actions that puts at risk the habit of endangered species, and it prohibits the appropriation of any endangered animal by any person.
- **Safe Drinking Water Act (SDWA):** Approved in 1974, this act requires that EPA set maximum pollutant limits in drinking water public systems. This act was amended in 1996 to require a further quick enactment of standards in order to introduce some flexibility in the current established standards.
- **Toxic Substances Control Act of 1976 (TSCA):** This act provides the EPA with comprehensive authority to regulate or prohibit the manufacture, distribution, or use of chemicals that

represents non-reasonable risks. It demands the EPA notification before manipulation of new chemicals, or new usage of existing chemicals.

- **Resource Conservation and Recovery Act of 1976 (RCRA):** It determines that EPA establishes regulations that assure the safe management of dangerous waste. The act was amended by Hazardous and Solid Waste Amendments in 1984 (HSWA) that imposes new technologies based in standards related to sanitary landfills with dangerous waste, and it increased the federal authority over non-dangerous solid waste disposal.

- **Comprehensive Environmental Response, Compensations, and Liability Act of 1980 (CERCLA):** This act establishes the objective liability system to release dangerous substances, and it creates a superfund to finance depollution actions. It was amended in 1986 to expand the superfund, imposing numerical objectives and deadlines to clean polluted zones. This act specifies standards and procedures to be followed, and it determines the level and scope of cleaning actions.

- **Emergency Planning and Community Right-to-Know Act (EPCRA):** Approved in 1986, this legislation requires that corporations and companies notify in detail the local authorities about the use of any toxic substance, and that they make annual reporting of quantities of chemicals released in the environment.

In turn, the relevant American doctrine divides the National Environmental Laws into six historical steps: the common law and conservation age (previous to 1945); federal aid to State problems (1945-1962); growth of modern ecological movements (1962-1970); construction of regulatory federal infrastructure (1970-1980); expansion and refining of regulatory strategies (1980-1990); and current phase of regulatory retreat and re-invention.

The Evolution passing by centuries of Law development with precedents and doctrinal evolutions of common law, by the Keynesian and welfarist Government, by the awareness of international community about matters linked to development and environmental crisis, by the neoliberalism age and its defeat, and obviously by current times in pursuit of sustainable development in the age of climate changes.

The environment protection in the Unites States is not promoted by the State and federal authorities only, but also by the citizens the through filling of lawsuits. There are several requirements to recognize the environmental plaintiff standing in the US, with difficulties to make use of Justice. The citizen should demonstrate:

- To own a standing to be analyzed in the factual case to contest a State or federal authority's act or omission;
- Depletion of administrative branch actions before the lawsuit;
- Documentation of the case under conditions to be judged;
- Presence of either current or future damage, not necessarily economical, that affects the plaintiff's individual rights.

A comprehensive environmental legislation authorizes any citizen or person to propose a citizen suit due to law infringement or due to non-conformity of pollutant emission standards. Although the citizen suit provision in paragraph 304 of the Clean Air Act acts as a model to most of such actions, the citizen suit in the Clean Water Act is the basis to most of these demands only.

The citizen suit may be promoted against the State, government agency, or corporation that is infringing a standard of effluents or limiting the provision in the regulation laws, or even failing to comply with order issued by the Federal agency or State itself referring to the level of emissions. The citizen suit may also be promoted against a Federal agency if there is alleged fail to comply with the law or duty provided in the Clean Water Act.

According to the law, a citizen is "any person with an interest or right that may be adversely affected by environmental damage" [9]. As already recognized by the case law, the citizen suit is only a supplement, not an alternative for the State action in terms of environmental protection. The legislature did not intend that the citizen is always a potential intruder over the discretion of federal agencies. In the regulation of both water and air pollution, the citizen cannot demand if the administrator or the State had previously filed a civil or criminal action in state of federal court according to the diligent prosecution doctrine.

In short, some environmental judicial demands in the United States are proposed based in former common law doctrines, and they are mostly based in the environmental legislation approved by the Congress, notwithstanding what is sometimes asserted. The State, federal agencies, and citizenship have standing for the legal environmental protection, provided that private laws and interests are infringed, insofar as the 1787 Constitution, the Bill of Rights amendments, and further constitutional amendments, as well as

the Supreme Court precedents did not classified the environment as independent asset that is worthy of specific constitutional protection, as in Brazil.

There is an expectancy among ambientalists that the Supreme Court, currently hesitant in deciding about the environment in the last decades — EPA v. Massachusetts (2007) was an exception —, may change its position after the death of the conservative justice Scalia due to a heart attack in a fishing station last year.

The possible assignment of a liberal justice in a replacement is the hope to create favorable environmental precedents in the coming year.

Therefore, we will approach the main theme of this study, and we will get to know a little about necroleachate and its impact to the environment and public health.

Necroleachate

The pollution caused by necroleachate is something old, but became public in recent times.

The non-decomposition of corpses through natural phenomena such as saponification (the corpse does not decompose and remains like a wax) in sandy and well-drained soils is the biggest problems to the present matter. Without a suitable decomposition, such corpses become a barrier to the environmental harmony and balance, because they prevent the release of grave for reuse, enlarging and complicating a lot the provision of cemetery fields.

Since each corpse occupies about 2.3 square meters, in the course of time, the disposal of remains becomes an issue gaining more dramatic outcomes in big cities.

It is a serious fact that has similarity with different environmental impacts.

In view of this problem, some solutions have been studied during this short period of time, such as establishment of necroleachate-absorbent coverings having a plastic material made of resistant cellulosic layer and a powder that turns into gel if contacted by a liquid, and also the application of tablets with a huge quantity of selected bacteria (2 billion colony-forming unit per gram- UFC-g) and high capacity to digest organic matter, both disposed in the urn with the corpse.

There are other solutions such as the construction of ecological cemeteries meeting all of the environmental requirements that are equipped with a modern system preventing contact of necroleachate with the soil and avoids the groundwater contamination; it is also equipped with a piping system of gases coming from decomposition, and an activated charcoal filter that cleans the air. We can also find the vertical cemeteries. According to ANJOS (2003), the legislation requires from these cemeteries:

- The construction of loculus (vertical graves made of reinforced concrete)
- Materials that prevent the gas inlet in places where visitors and workers are passing.
- Materials with constructive characteristics that prevent the leakage of necroleachate
- A device that allows gas exchange and provides suitable conditions to the corpse decomposition;
- Environmental treatment suitable to gas effluents.
- Finally, the crematoriums that has the advantage of non-interference by necroleachate in groundwater, the containment of microorganisms, which may interfere in the environment.

Rainwater infiltration in the graves results in transport of several chemical compounds (both organic and inorganic) that may reach and contaminate the aquifers depending on the land geological features (KEMERICH and BORBA, 2013).

If there is contamination of aquifers in the cemetery inner side, this area becomes not only potentially polluted, but also the surrounding areas, increasing the risk of waterborne diseases for people in contact with contaminated water (KEMERICH; BIANCHINI; FANK., *et al*. 2014).

The majority of pathogenic organisms does not tolerate oxygen in the soil unsaturated zone, and they are eliminated. However, oxygen depletion in deeper aquifers allows abundant development of microorganisms. In the case of drinking water intake from small depth-wells, individuals and animals that use this water are under risk of developing diseases caused by such organisms (KEMERICH; BIANCHINI; FANK., *et al.* 2014). KEMERICH; BIANCHINI; FANK., *et al.* (2014), state that gases released by corpse decomposition are toxic in some cases, for example:

- H_2S - Hydrogen sulfide - extremely toxic and flammable, it causes damages to health, even death.

- CH_4 – Methane - the reaction of methane is combustion;
- NH_3 – Ammonia - toxic and easily dissolved in water;
- CO_2 – Carbon dioxide - odorless, colorless, suffocating;
- H_2 – Hydrogen - colorless, odorless, tasteless, and non-toxic.

In addition to such gases, we also verify the emission of metal oxides (titanium, chromium, cadmium, lead, manganese, mercury, and nickel, among others) leachate from the urn attachments, including formaldehyde and methanol used in the practice of embalming.

Whenever forensic experts find a corpse, in the case of either murder or suicide, it is important to assess the decomposition time-lapse, even due to concerns with possible local environmental contamination.

Thus, it is possible to estimate the death interval, in other words, how long has passed from the individual's

death until the corpse is found.

We will now understand a little more about TAPHONOMY.

The science that studies and describes the processes involved in decomposition of corpses is called taphonomy, coming from the Greek taphos (burial or grave) and nomos (laws), literally translating, it can be considered as the laws of interment. The best taphonomy experts in general are not the CSI, but they are archaeologists, paleontologists, and anthropologists.

When a corpse is investigated, the different "physical evidences" need to be categorized into three intervals: Antemortem, Perimortem and Postmortem.

- **Antemortem:** This refers to the interval of facts before the death of a victim, sometimes not related to the case, because they are life experiences. They are characteristic due to the skin or bone healing, as they had time to regenerate.
- **Perimortem:** Refers to the interval and facts during the death of near it. Unlike antemortem injuries, there was no healing time here.
- **Postmortem:** There is not an exact barrier to determine the end of perimortem interval and the beginning of postmortem, becoming a big challenge to experts. However, decomposition processes may indicate the transitions.

We have to bear in mind that such periods are artificial and used by convention to categorize evidences and injuries. The priority of taphonomy is the study and description of processes in the postmortem interval - PMI, in which forensic pathologists study perimortem intervals.

The body decomposition has several variables, the main are temperature and insects in the corpse. Thus, PMI may vary in different locations, mainly in relation to temperate and polar regions where decomposition rates are near to zero and the body freezes. Therefore, it is important to validate the PMI estimate in several places of the world.

Decomposition stages

Although it is not a recent study, the taphonomy does not have a universal stage for all decomposition stages yet. However, we will discuss one of the most used patterns by researchers and CSI, described by Payne (1965) and divided into six stages using pigs in an average soil temperature of 26.1^0C. (The images are from the Australian Museum for reasons of quality).

- **Fresh (day 0):** Initial stage, basically, without any visible strong decomposition characteristic. It is exactly here were we found difficulties between the perimortem and postmortem interval. The smell is still present in the animal (or person) when alive. After some time-lapse (minutes or hours, varying as the region), the first flies of the Calliphoridae family (largely used in Forensic Entomology)
- **Swollen (day 1):** The name given by the main characteristic of the stage, corpse swelling due to concentration of gas released by decomposition bacteria. The strong putrefaction smell is present, as well as other types of flies, ants, and some scavenger beetles.
- **Active decomposition (day 3):** Insect larvae enter into the holes, skin and other tissues, then body gas and fluids are largely released in the environment, attracting even more animals and accelerating the decomposition process.
- **Advanced decomposition (day 5)** – In this stage, most of entrails were devoured by insects and other organisms. The bones are gradually exposed, the body loses volume and the strong smell begins to decrease, as well as the diversity of insects.
- **Dried (day 7):** We find only skin, cartilage and bones. Other arthropods take advantage of competition decrease to obtain resources, such as centipedes, snails, millipedes, among others.

- **Remains:** It is difficult to determine when the last phase is initiated, but the carcass is already in this category probably within two weeks. The smell is weak, but quite impregnated in the soil and surrounding rocks. All flesh and skin are absent, only bones and hair are present, and animals are from the environment at all, not those linked to the decomposition process.

Other challenge to CSIs is that decomposition rate not always occur uniformly in the corpse, where it is important to carefully assess and use different techniques to diminish the estimate imprecision.

Each characteristic in different stages are fundamental to the detailed knowledge of decomposition process, understanding the mechanisms and consequently offering different information about the death. Any small variation may change this chemical process, such as clothes, environment, local body change, local biodiversity, and mainly the insects. When insects cannot access the body, the mummification process takes place. One example is the case of the German Manfred Fritz Bajorat, who died inside the boat, as insects could not access the corpse, because the boat was adrift, he mummified.

After death, the human body is decomposed, as well as any other living being. It serves as an ecosystem to other organisms such as arthropods, bacteria, pathogenic and scavenger microorganisms and others, posing a risk to the environment and public health.

During the decomposition process, a liquid called "colliquation liquid" is released, also known as necroleachate. This liquid is the responsible for contamination of soil and groundwater.

Necroleachate is viscous, grayish brown, strong smell and variable degree of pathogenicity (ALMEIDA e MACÊDO; 2005).

It shows an average density of 1.23 g/cm3 (thicker than water), and the ratio between produced necroleachate volume and body weight is 0.60 L/Kg (LOPES, [200-]).

According to Almeida e Macedo (2005), the decomposition of body organic substances may produce diamines such as cadaverine (C5H14N2) and putrescine (C4H12N2) that generates NH4+ when degraded, a substance with high rates of toxicity. Cadaverine and putrescine are dangerous because they are also responsible for the transmission of infecto-contagious diseases such as hepatitis and typhoid fever.

Such substances may spread within a radius higher than 400 meters length from the cemetery, depending of the region geology (LOPES, [200-]). After death, as cited above, bacteria, virus, and pathogenic microorganisms infest the human body. They have the capacity to seep the soil with the aid of water, contaminating the cemetery groundwater. Virus and bacteria have a very high resistance in the soil, particularly in the water. They may cause epidemics if they reach the groundwater in fact.

According to the World Health Organization – WHO (1998), typical organisms present in aquifers that cause diseases are *micrococcaceae, streptococcus, bacillus*, and *enterobacteriacea*. WHO (1998) stated that coliform bacteria was detected in groundwater of Brazilian cemeteries located in the State of São Paulo.

The virus are easily fixed by soil particles than bacteria, the reason why the latter reached the aquifers.

According to Lance e Gerba cited by WHO (1998), negative virus lower than a certain level are immediately adsorbed while strong positive virus are moved to furthermost places. This difference is explained by the soil constitution and its chemical properties. Clay has very tiny negative grains. When highly-electron charged virus pass by clay grains they are expelled due to equal charges. On the other hand, less-electron charged virus remain in the grains due to chemical affinity (cation exchange).

For this reason, it is fundamental to study the soil below the location where the new cemetery will be implemented.

The coffins are also important in the maintenance process of the system environmental quality. They must be constructed by materials that can rapidly decompose and cannot release persistent chemicals in the environment.

Cemeteries may cause environmental pollution both in the groundwater and regional soil not only due to toxicity of necroleachate and pathogenic microorganisms.

The natural concentration increase of organic and inorganic substances previously present, or in the soil, is a factor that needs to be analyzed against risks yet. Changes in the natural environment should be deemed as important and closely followed-up by environmental authorities, because they disable the soil and aquifer.

Necroleachate mobility in the environment

- Generally, when contaminants enter into the soil they suffer some reaction that can retain it, freely let it go, or soften it in a solid mean.
- The contaminant behavior depends on its physical and chemical properties and the environment where it has leaked.
- Necroleachate is deemed as a contaminant and its movement in the soil should be investigated before the cemetery construction. Sandy soils have bigger grains, and consequently smaller surface areas. This implies that cemeteries does not have capacity to retain water or contaminants in itsinterstices.
- Sandy soil is biologically poor. Clayish soil can retain liquids because its grains are tiny and its surface is larger, where liquid molecules are able to remain absorbed.
- To retain water or contaminants from clayish soils, a higher pressure than sandy soils is necessary. This is explained by the capillarity in clayish soil - thinner interstice generates higher retention pressure (OLIVEIRA, 2008).
- The pollutant mobility in the soil is measured by its hydraulic conductivity. Hydraulic conductivity depends on the molecular weight and pollutant density, and it means the infiltration speed in the saturatedsoil.
- There are no sufficient researches studying the behavior of necroleachate in the soil. It is known only that its density is higher than the water. This enhances the soil infiltration until it reaches the aquifer. However, according to WHO (1998), researches show that there is a mitigation of necroleachate in the soil unsaturated zone. There is air in the soil unsaturated zone, then we find higher concentration of aerobic microorganisms that consume necroleachate more efficiently than under anaerobic conditions. Thus, it is advisable that the soil above the coffin is not compacted in the backfill so that there is greater aeration of the corpse.
- On the other hand, the aeration releases toxic and extremely smelly gases to the atmosphere. The mitigation of necroleachate is more efficient in clays, since they have more microorganisms inside. To guarantee a greater degradation of necroleachate before it reaches the aquifer, it is advisable to keep the grave as far away as possible from the aquifer. Thus, there will be more solid layer for the passage and degradation of the pollutant.
- Viruses in necroleachate are adsorbed in the clay grains, making it difficult to reach the aquifer. However, in sandy soils and gravels, viruses may reach long distances. (DUBOISE, 1976 apud WHO, 1998).
- The rain helps in the necroleachate percolation and infiltration in the coil until it reaches the aquifer. With rain, the hydraulic charge is higher over the soil that increases the speed of infiltration. The faster the contaminant passes the soil, the less time it will have to be degraded and adsorbed. According to O'Brien e Newman (1997) cited by WHO (1998), plants my remove virus and bacteria from the soil, in addition of consuming part of the necroleachate organic load.
- Trees also retain rainwater that transports the contaminants to the aquifer. Aquifer water level is reduced in places with large trees since they can absorb the groundwater.
- This phenomenon increases the biodegradation capacity of necroleachate by the soil. After all processes in the soil, if the necroleachate reaches the aquifer capillary fringe, it will pass through the aquifer because it is thicker than water.
- When necroleachate is found inside the aquifer, it can be dissolved (depending on the solubility), carried in the sense of aquifer flow, or it can be deposited in the lower waterproof layer of the aquifer. Although necroleachate density is higher than water (d = 1.23 g/cm^3), its value is not so high to the point that all pollutant pass through the aquifer until its waterproof layer. With his, a portion of necroleachate should be transported with the aquifer in the water flow sense, spread by the region.

Necroleachate environmental impacts

- Cemeteries are deemed as pollutant sources because they are constructed without any concern about covering the lower layer of the soil so that the necroleachate released in the corpse decomposition does not reach the soil and aquifer.
- Contamination by necroleachate may be caused by increase of organic matter in the environment that leads to a series of harmful changes to the ecosystem harmony, or it may be caused by the spread of pathogenic microorganisms, such as viruses and bacteria. Because it is thicker than the water, necroleachate migrates to its lower part until reaching the waterproof layer, when it reaches the aquifer.
- From there, part of it can follow the water flow or be drained over the aquifer waterproof substrate. Such aquifer contamination

is a big problem to be solved, because it is generally found in higher depths.

- In addition, it is necessary to construct hydraulic barriers to remove the contaminated water and decontaminate the aquifer, so that its treatment takes place *ex situ*, reducing the aquifer hydraulic load.
- When necroleachate reaches the aquifer, it is carried to farther locations. If necroleachate still has contaminants when it reaches the aquifer, the source will be impaired.
- More resistant viruses and bacteria contaminates the water and make it unsuitable for human consumption. For this reason, it is indispensable to know them deeply (WHO, 1998) [1]. On the other hand, studies stated by WHO (1998) confirm places where the contaminant plume quickly diminish with the grave distance, probably due to the biological degradation of soil microorganisms. In Holland, other study indicated large plumes with high-chloride, sulfate and bicarbonate concentration below the graves.
- None information has been given about the type of soil in these studies. Increases in electrical conductivity or salinity near to recent graves have been measured in the Australian botanic cemeteries. Elevated concentration of chloride, nitrate, nitride, ammonia, phosphate, iron, sodium, potassium, and magnesium ions were found below the cemetery, soil, and in the groundwater.
- Groundwater was considered suitable for irrigation, as specified in the criteria for Australian water quality. (DENT, 1998 apud WHO, 1998) [1]. XV Brazilian Groundwater Congress.
- The highest impact research in Brazil about groundwater contamination by cemeteries was made by PACHECO., *et al*. (1991) who studies three cemeteries in the cities of São Paulo and Santos, and they found groundwater contamination by microorganisms - total coliforms, fecal coliform, fecal streptococcus reducing sulphite clostridia, and others coming from decomposition of buried corpses in the soil. The risk of biological contamination with the cemetery construction is urban environment is presumed.

Groundwater is more affected due to virus and bacteria contamination. Natural sources or shallow wells connected to the contaminated aquifer may transmit waterborne diseases such as:

- Tetanus,
- Gas gangrene,
- Food poisoning,
- Tuberculosis, typhoid fever,
- Paratyphoid fever,
- Hepatitis a fever, among others (LOPES, [200-]).

Among all contaminations caused by cemeteries, the biggest problems are related to the viruses due to its great capacity for survival, mobility, adaptation to adverse environment, mutation and permeation through semipermeable means.

Virus contaminant vectors were found miles away from the cemeteries. Vectors may still cause problems to the vulnerable population that consumes the contaminated water (LOPES, [200-]).

Due to the complexity of negative impacts caused by necroleachate, forms of treatment of this substance have increased in order to transform into a less toxic and pathogenic product (FELICIONI; ANDRADE; BORTOLOZZO, 2007).

For the effective treatment of necroleachate, it is necessary that the cemetery has an ecological structure and that it complies with the above environmental rules.

According to CASAGRANDE (2018), there are today several treatment methods and technologies to necroleachate; among them we can mention:

- Biological filters;
- Tablets;
- Absorbent coverings.

For the method of biological filters, firstly we should place in the soil below the graves a coating named waterproofing membrane that will protect the groundwater from necroleachate contamination (BRASIL, 2003).

Next, we should construct drains that will direct the necroleachate and rainwaters to the biologic filters, where they will be degraded by porous means through thick materials, such as rocks, gravels, stones and concretes (CASAGRANDE, 2018).

Depending on the filtering material, for example, a concrete filter, this material shows efficiency to remove the necroleachate color (JALOWITZKI, 2011).

The efficiency of this method depends on the distance among the graves and filter, since that the greater the distance, the greater the time to liquid pass will be, and then necroleachate may not reach the filters to receive the necessary treatment [1-17].

Conclusion

- The burial culture is spread by the society around the world. Cemeteries are polluting and contaminating sources to the soil and groundwater. Its consequences affect the health of people living or not near to cemeteries, due to the contaminant advection capacity.
- In view of the need to increase the burial locations in countries with limited territories, we need to identify more precisely harmful impacts to the environment and public health.
- To minimize environmental impacts generated by the corpse decomposition, a greater concern with the selection of cemetery construction sites and methods.
- We should avoid much permeable soils such as sand, gravel, and permeable stones. The most advisable soil to maximize the retention of degradation products is a mix of gravel and low-porosity sand, and a small percentage of fine texture grains.
- Such as in sanitary landfills, the construction of an underground layer that works as a barrier to prevent soil and groundwater contamination by the leachate produced in the garbage decomposition can be studied.
- I recommend a distance between the grave bottom and the groundwater, depending on the soil permeability. Trees that retain microorganisms and consume the surplus organic matter can be planted in the environment to help in the retention of leachate contaminants.
- The distance until the water level (non-saturated zone) helps in the effective degradation of viruses and bacteria by natural soil microorganisms, by absorption, by the root action and by the adsorption of soil particles working as a filter. The greater the distance, the more necroleachate will remain in the soil, and then, it will be degraded.
- Other important point is the height difference between cemetery and surrounding area. A cemetery should not be located in the lower part of an area, where rainwaters are concentrated.
- The water enhances the infiltration speed of necroleachate by the soil and reduces its degradation potential.
- The construction of cemeteries should be made judiciously to guarantee the maintenance of environmental quality. Geological and sanitary studies of cemetery fields and the verification of soil and groundwater contamination potentialities are necessary.

Finally, we have to ratify the relevance of extra care with the Covid-19 issue, a new coronavirus (SARS- COV-2) that was identified as the cause of acute respiratory disease (COVID-19). In January 2020, the World Health Organization (WHO) declared this outbreak as a Public Health Emergency of International Concern (PHEIC), and in March 2020, with the spread of the virus to different countries, it was declared as a pandemic.

The transmission of COVID-19 takes place by personal contact and by fomites. I emphasize that SARS- COVID-2 virus may keep itself practicable on environmental surfaces for 24 hours or more.

Infectious disease transmission may also occur by means of body manipulation, especially in health equipment. A scenario of absence or improper usage of PPE - Personal Protective Equipment, aggravates this. In this context, the practitioners responsible for the body care are exposed to the risk of infection.

The funeral of patients having confirmed/suspected COVID-19 are not recommended due to the agglomeration in closed environments. In this case, the risk of transmission is also linked to the contact between relatives and friends.

This recommendation should be noted during periods with indication of social isolation and quarantine.

Autopsy should NOT be made, being unnecessary in case of COVID-19 antemortem confirmation. Due to the increased complication risk of COVID-19 worse prognosis, it is recommended that practitioners aged 60 years or above, pregnant, lactating, individuals with chronic, cardiopulmonary, and oncological diseases or immunodepressed individuals are not exposed to activities related to the manipulation of confirmed/suspected COVID-19 bodies.

According to the concern with body manipulation in the context of COVID-19, since SARS-COV2 is transmitted by personal contact, it is fundamental that practitioners are protected against infected blood and body fluid exposure, as well as objects and other contaminated environmental surfaces.

The personal protective equipment (PPE) recommended to the team that manipulate the bodies in this stage are:

- Cap;
- goggles or face shield;
- Long waterproof apron;
- Surgical mask; If necessary to carry out procedures that generate sprays, as decannulation or collection of respiratory samples, use N95, PFF2, or equivalent.
- Gloves; Use nitrile gloves for manipulation during the whole procedure.
- Waterproof boots.
- Carefully remove tubes, drains, and catheters from the body due to the chance of contact with body fluids.
- The disposal of materials and clothes should be immediately carried out in suitable place
- Clean and block the wounds and catheter puncture drain holes with waterproof coverage;
- Clean the secretions in the oral and nasal holes with compress;
- Block the natural holes (mouth, nose, ear, anus) to prevent the leakage of body fluids;
- Limit the body recognition only to one relative/responsible.
- We suggest none contact between the relative/responsible and the body, keeping a distance of two meters among them;
- If approximation is necessary, the relative/responsible must use a surgical mask, gloves and protective aprons;
- Furthermore, we suggest that photos, depending on the structure, may carry out the body recognition preventing the contact and exposure.
- During the packing that should be done in the death place, body manipulation should be the least possible, preventing procedures that generate gases or leakage of body fluids;
- Preferably, identify the body with name, record number, number of
- CNS (National Health Card), date of birth, name of mother and CPF (Individual Taxpayer Identity Number), using an adhesive tape, with legible handwriting fixed in the thoracic region;
- It is essential to record data in the record relative to all external signs and birthmarks/tattoos, orthotics, prosthesis that can identify the body;
- Tanatopraxia is NOT recommended (formaldehyde application and embalming).
- If possible, the package of body should follow three layers: 1st: wrap the body with sheets; 2nd: place the body inside a suitable waterproof bag (it should prevent the leakage of contaminating body fluids). 3nd: place the body in a second bag (external) and disinfect with alcohol 70%, chloride solution 0.5% in 1%, or other authorized sanitizing agent suitable with the bag material.
- Place a tag with the deceased identification.
- Identify the transportation external bag with information related to biological risk: COVID-19, biological agent risk class 3 (waste from infectious diseases).
- In the mortuary, the corpse should be placed in urn to be sealed before the delivery to relatives/responsible;
- The sealed urn surface should be cleaned with chloride solution 0.5%;
- After sealing, the urn should not be opened;
- Practitioners working in the transportation, keeping, and allocation of body in the coffin should also adopt precautionary measures exposed here until the coffin is closed;
- The funerary/transport service should be informed that it is a victim of COVID-19, biological agent risk class 3;
- After the body manipulation, remove and dispose the gloves, mask, apron (if disposable) in infections waste;

The funeral of patients having confirmed/suspected COVID-19 are NOT recommended during social isolation and quarantine.

If made, we recommend:

- Keep the funerary urn closed during the whole funeral, preventing any contact (touch/kiss) with the deceased body at any post-mortem time;
- Provide water, soap, paper towel, and alcohol gel 70% to clean the hands during the funeral;
- Place the urn in open and ventilated place;
- Specially prevent the presence of people in the risk group of COVID-19; aged 60 or higher, pregnant, lactating, chronic disease and immunodepressed individuals;
- Prohibit the presence of people with respiratory symptoms, complying with the legislation referring to quarantine and compulsory hospitalization within National Relevance Public Health Emergency (ESPIN) by COVID-19.

If indispensable, they must use common surgical masks, remain in the place the least possible, and prevent physical contact with others

- Prohibit the presence of foods. For drinks, it should be noted the measures to prevent the shared cups;
- The funeral should not have agglomeration, respecting the minimum distance of at least two meters among them, as well as other measures for social isolation and respiratory tag;
- It is recommended that the burial occur with a maximum of 10 individuals, not for the body biological risk, but due to the contraindication of agglomerations.

It is critically important to pursuit alternatives for necroleachate treatment after the pandemic in order to prevent greater impacts to the environment and public health. Comparing the burial with cremation, we can conclude that the cremation act is the most efficient, hygienic and less environmental impact method, being deemed as the most ecological process, not affecting the environment.

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