Applying Ionizing Radiation to Metal Speciation for the Environmental Assessment of Underground Aquifer Associated with Technogenic Landfill Containing Sludge from A Water Treatment Plant (WTP)

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Technologies based on Advanced Oxidative Processes (AOPs), which promote chemical changes in the substrate, can also lead to the complete mineralization of metallic chemical elements [11,12]. In addition, AOPs may be used to treat contaminants whose concentration is very low (ppb) [13,14], as it happens to some metals.

The interaction between energetically charged particles (electrons, photons, and alpha particles), highenergy photons (gamma rays and x-rays) and matter mainly leads to the ionization and excitation of the medium where radiation is absorbed in. Ionized and excited molecules, as well as free electrons, are produced when water molecules are irradiated.

Photochemical reactions generated by radiation are generally radical and based on hydroxyl radical formation (HO•) a highly reactive oxidizing agent capable of breaking covalent bonds and inducing the complete mineralization of organic compounds found in the sample.

In addition, this procedure significantly reduces mineralization time and reagent amounts, fact that minimizes the possibility of contaminating the sample [15,16].

The Production and Disposal of Sludge from Water Treatment Plants (WTP)

Social demands for improvements in quality of life involve issues related to environmental sanitation; thus, the water applied to several human activities must present features able to meet the quality standards and criteria for human consumption, or potability standards. The World Health Organization (WHO) internationally set criteria and parameters for drinking water for human consumption followed by the Brazilian Ministry of Health [17].

The option for water treatment technology should take into consideration the physicochemical features of the raw water to be treated in order to allow removing or reducing certain constituents found in it.

According to NBR 12.216 (ABNT), a Water Treatment Plant (WTP) is the set of units designed to adapt water features to the potability standards set by the Brazilian Ministry of Health. The implementation of water treatment systems depends on environmental licensing, according to Resolution 237 issued by the National Environment Council [18].

The water treatment systems used by most water purification industries in the world, including Brazil, comprise coagulation, flocculation, decantation or sedimentation processes, as well as filtration and disinfection; these systems are generically called conventional water treatment plants [19,20].

The addition of aluminum sulfate or ferrous sulfate leads to coagulation; compounds formed during the coagulation stage present adsorption property. These particles present superficially positive electric charges, whereas the impurities in the water such as suspended matter, colloidal substances, as well as some dissolved salts and bacteria, present negative electric charge. Thus, flakes retain suspended impurities, and it enables decantation in the form of sludge. The produced sludge is a non-Newtonian, gelatinous fluid whose solid fraction consists of aluminum hydroxide or iron hydroxide, inorganic particulate matter, polymers, colloids and several organic compounds; it presents low compressibility, high volume and low solid content.

The production and disposal of sludge derived from WTPs is already taken into consideration in several countries; it has been a worldwide tendency to consider sludge a product, rather than a waste, since it adds value through reuse [21].

Although the sludge generated in WTPs is considered solid waste by the legislation (ABNT, 2014), in many Brazilian regions, this waste is released in natura in areas that were not prepared for such disposal, fact that does not comply with public environmental sanitation policies.

The installation of WTPs should be preceded by a system sizing stage, which may be carried out through tests or at laboratory scale, since raw water composition turbidity, suspended solids, among others changes depending on the season [22].

The seasonal character in the composition of the water to be treated would require a preliminary study about sludge production by the WTP for at least one year, fact that makes this procedure economically unfeasible. Thus, projects end up dimensioning sludge production through empirical formulas, although they do not represent the water resource reality.

The sludge features may be related to environmental aspects (pH, solids, metals, COD, biodegradability, toxicity, pesticides, fertilizers and volatile organic compounds) associated with waste disposals. Also, to geotechnical aspects (particle size and size distribution, plasticity and liquidity limits, specific resistance, heating and cooling responses and sedimentation) related to water removal and to future uses of solids from wastes [23,24].

Study Site

The Taiaçupeba Water Treatment Plant and Dam (Taiaçupeba WTP), which is managed by São Paulo State Basic Sanitation Company (SABESP Cia. de Saneamento Básico do Estado de São Paulo), is located in Suzano County, Metropolitan Region of São Paulo (RMSP Região Metropolitana de São Paulo), Brazil. The dam composes the Alto Tietê Producer System (SPAT Sistema Produtor Alto Tietê), which is the third largest Integrated Water Production System whose adductors supply the RMSP.

The SPAT is formed by Tietê River headwaters, which are regularized by Ponta Nova (Tietê and Claro Rivers), Paraitinga (Paraitinga River), Biritiba (Biritiba River), Jundiaí (Jundiaí, Rio Grande and Doce Rivers) and Taiaçupeba Dams (Taiaçupeba Mirim, Balainho and TaiaçupebaAçu Rivers) (Figure 1).

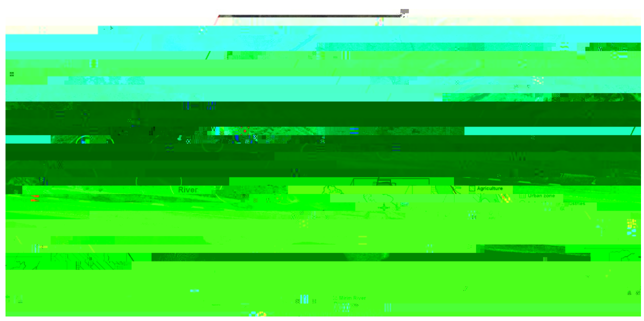

Figure 1: Location area (Fn=monitoring wells).

The sludge generated at Taiaçupeba WTP from 1992 to 2004 was discarded in the reservoir located downstream of the WTP catchment. At the request of São Paulo State Basic Sanitation Company (CETESB Companhia de Saneamento Básico do Estado de São Paulo), the sludge once discarded in the lake was partially removed from February 2005 on. Part of it was taken to be treated along with the sludge generated in the desiccators in the sludge densification and disposal system (ADSL), at the ratio of 60 tons of WTP sludge to 90 tons of sludge from the lake. The material was sent to the drying area, in covered furrows and, after drying, it was stored in

Samples	CE (µS/cm)	pH	T (°C)	STD (ppm)	Salinidade (‰)	Eh (mV)
F1	372.5	5.96	21.51	186	0.18	8.9
F2	638	5.89	24.88	319	0.31	-18.9
River	89	4.96	21.78	44	0.04	-11
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