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ASSESSING THE RISK OF GROUNDWATER CONTAMINATION FROM ORGANIC SUBSTANCES IN SEWAGE SLUDGE

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ABSTRACT: In this work, the risk of groundwater contamination from organic substances in sewage sludge from wastewater treatment stations was evaluated in its worst case. The sewage sludge was applied as fertilizer in corn culture, prioritizing the substances for monitoring. The assessing risk took place in a Typic Distrophic Red Latossol (TDRL) area, in the county district of Jaguariúna, SP. The simulators CMLS-94 and WGEN were used to evaluate the risk of twenty-eight organic substances in sewage sludge to leach to groundwater. The risk of groundwater contamination was accomplished for a single sludge dose application in a thousand independent and equally probable years, simulated to esteem the substances leaching in one year after the application date of the sludge. It is presented the substances that should be priorly monitored in groundwater.
KEYWORDS: simulation, leaching, CMLS-94, WGEN.

INTRODUCTION: The initial control stage of water pollution usually concerns the sewage treatment, leaving in second plan the solution of the sludge problem generated from treatment of the liquid phase and its appropriate final destination. In agreement with OAK & BARRAL (1981), among the existing alternatives, the use of sludge in agricultural areas is the one that presents lower costs and causes less damages to the atmosphere. In Brazil, represetative studies on sewage sludge environmental impacts were addressed to pathogenic organisms, heavy metals and nitrates (ANDRADE & MATTIAZZO, 2000; BOEIRA et al., 2002; ROCK et al., 2003). However, the occurrence of persistent organic pollutants in sludge has been growing because of the increase of synthetic substance production, of several natures, in the chemical industry (PARAÍBA & SAITO, 2005).

Mathematical models can contribute to predict the destination and the environmental preference of pollutants, and they can suggest which of them and in which compartments they should be observed systematically in monitoring programs of agricultural practices that long for being economical and environmentally sustainable (PARAÍBA & SAITO, 2005). One inherent risk of using sewage sludge refers to the possibility of groundwater contamination by the organic pollutants leaching present in sludge. This study used the model of transport chemical substances and the climate simulator in order to identify which organic substances present in sludge from wastewater treatment stations of the county districts of Suzano and Barueri, SP, should be monitored in groundwater.

METHODOLOGY: In a total of fifty seven organic substances present in sludge from wastewater treatment stations of Barueri and Suzano, twenty eight substances were studied due to its larger environmental and human health importance (TSUTIYA, 2001). For simulating the leaching potential of these substances, the simulator used was the CMLS-94, "Chemical Movement in Layered Soils" (NOFZIGER & HORNSBY, 1994). It can be used to estimate the movement of organic chemicals in uniform soil (homogeneous) in response to downward movement of water. The model also estimates the degradation of the chemicals and the amounts remaining in the soil profile. The parameters required by the model are: climatic (maximum and minimum temperatures, and precipitation), substances (organic carbon partition coefficient, degradation half-life in the soil and concentration), soil (organic carbon content, bulk density, volumetric water content in field capacity, permanent wilting point, and saturation) and cultural coefficients.

Climate generators are mathematical models for simulation that esteem the occurrence of climatic variables and generate a group of numeric values, denominated synthetic series, with statistical characteristics of historical series. WGEN, "Weather Generator", developed by RICHARDSON & WRIGHT (1984), is a mathematical simulator that generates synthetic series of climatic data. CMLS-94 incorporates WGEN allowing the evaluation of the leaching risk of substances using synthetic series of independent and equally probable climatic data.

Individual scenarios were elaborated combining substances, soil and corn culture to simulate the dynamic of the twenty-eight selected organic substances - each one with an initial concentration of 1 $mg.L^{-1}$. The simulations were accomplished for a period of fourteen consecutive years (from 1993 to 2007) for all of the individual scenarios, using meteorological data from Campinas, SP, supplied by the Agronomic Institute of Campinas (IAC). The soil data used in this work is from the project "*Avaliação da translocação de alguns contaminantes orgânicos presentes no lodo de esgoto para o produto agrícola, visando á segurança do alimento*" (EMBRAPA/MP3-03.06.5.10.00.01/02), coordinated by EMBRAPA's environment researchers team. The project's central experiment is being conducted in the experimental field of the Unit, in a Typic Distrophic Red Latossol area; the daily data of air temperature (minimum and maximum) and of precipitation were typed in compatible format with CMLS-94 (temperatures in whole values and "juliano" year). The sludge was superficially applied on the soil on December 13th, 2006, and the planting of the corn culture was accomplished on December 18th, 2006.

RESULTS AND DISCUSSION: In CMLS-94 the leaching obtained depth in meters, and the concentration in $mg.L^{-1}$, for each one of the twenty-eight simulated organic substances (TABLE 1). Starting from this information, we could obtain the evaluation of the leaching potential of the substances in the soil profile after a year of the sludge application in the corn culture. Thus, among the substances, those with larger risk of groundwater contamination can be enumerated.

At the end of the simulations, it is verified that twelve substances reached significant leaching depths (more than 10 m): 2,4-dinitrophenol, n-nitrosodi-n-propylamine, 1,2-diphenylhydrazine, isophorone, nitrobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3,3-dichlorobenzidine, phenol and benzidine.

High concentration values are related to the high sorption capacity of the substance and to its persistence in the soil. The substances with smaller sorption values and half-life prove to be more leaching and, consequently, in smaller concentrations in the soil solution. The substance 2,4-dinitrophenol presented the largest leaching tendency, with significant concentration in the soil solution.

Supposing that the soil had been fertilized with a dose of 10 $T.ha^{-1}$ of sludge that contains 2,4-dinitrophenol in the concentration of 4.8 $mg.L^{-1}$, and those values provided from the surface to the depth of 0.2 m concentrations of 5.54×10^{-2} $mg.L^{-1}$ of the substance in the soil solution. (PARAÍBA et al., 2006) simulating the 2,4-dinitrophenol in these conditions, for a person of 70 kg, it would result in a daily ingestion of 1.1×10^{-3} milligrams per kilogram of corporal weight per day ($mg.kg^{-1}.d^{-1}$). This ingestion, in spite of being low, is on the same order of greatness of the reference dose (RfD) of $2,0 \times 10^{-3}$ $mg.L^{-1}.dia^{-1}$, defined by EPA for the 2,4-dinitrophenol (EPA, 1999). In conventional terms, RfD is an estimate of the daily exhibition of the human population to the chemical agent that would not cause appreciable risk associated to harmful effects throughout life (EPA, 1999). Thereby, groundwater table close to fertilized soils with sludge containing 2,4-dinitrophenol should be monitored in relation to this substance concentration.

Validation studies of CMLS and the comparison of its results with those obtained by other simulators, such as GLEAMS, PRZM, LEACHMP and MOUSE, whose differences and further information can be found in PERSON et al. (1997), were presented by PENELL et al. (1990). These authors report that the performance of CMLS was as good as the more complex simulators like PRZM and LEACHMP, and better than GLEAMS and MOUSE in the prediction of the leaching depth. They also emphasize that the CMLS performance was better than the others when the concentration distribution substances were appraised with the depth.

The results obtained by the simulations in this work are in accordance to those that prioritize organic substances in sewage sludge, using screening models, such as those introduced by WILSON et al. (1996), that accomplished assessment of the leaching potential of organic substances to groundwater. FALLS et al. (2007) that accomplished evaluation of the occurrence of organic pollutants from wastewater treatment stations in China.

TABLE 1. Leaching depth and concentration of the organic substances in the soil profile

Substance	Depth[1] (m)	Concentration[1] ($mg.L^{-1}$)
1,2,4-trichlorobenzene	1.50	2.5E-01
1,2-dichlorobenzene	3.00	2.5E-01
1,2-diphenylhydrazine	6.00	2.5E-01
1,3-dichlorobenzene	2.75	2.5E-01
1,4-dichlorobenzene	3.00	2.5E-01
2,4-dinitrophenol	25.00	3.8E-01
2-chlorophenol	15.00	2.2E-04
3,3-dichlorobenzidine	2.75	2.5E-01
anthracene	0.70	5.8E-01
benzidine	35.00	1.8E-14
benzo(a)anthracene	0.15	6.9E-01
benzo(a)pyrene	0.10	6.2E-01
benzo(k)fluoranthene	0.10	8.9E-01
dibenzo(a,h)anthracene	0.05	7.6E-01
hexachlorobenzene	0.15	8.9E-01
hexachlorobutadiene	0.45	2.5E-01
hexachlorocyclopentadiene	0.35	1.2E-04
hexachloroethane	1.20	2.5E-01
indeno(1,2,3-c,d)pyrene	0.05	7.1E-01
isophorone	22.50	1.2E-04
naphtalene	3.50	5.1E-03
nitrobenzene	20.00	1.2E-04
n-nitrosodi-n-propylamine	35.00	2.5E-01
n-nitrosodiphenylamine	4.50	5.9E-04
pentachlorophenol	0.60	2.4E-01
phenanthrene	0.70	2.8E-01
phenol	35.00	1.0E-11
pyrene	0.45	8.8E-01

[1] One year after the sludge application in the soil.

CONCLUSION: The substances 2,4-dinitrophenol, n-nitrosodi-n-propylamine, 1,2-diphenylhydrazine, isophorone, nitrobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3,3-dichlorobenzidine, phenol and benzidine are those that should be priorly monitored in groundwaters. The methodology used in the work was shown efficient to indicate the potential risk of groundwater contamination from organic substances in sewage sludges, resulting as a valuable tool for environmental monitoring. CMLS-94 and WGEN didn't present execution problems and the obtained results are in accordance with the literature.

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