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Assessment of health and ecotoxicological risks of hospital effluent from the Biamba Marie Mutombo Hospital and Bondeko Clinic in Kinshasa

Theddy Mbuma Mbabu[1], Hervé Ngangu Buloki[1], André Kanjinga Ngoyi[1,] Athanase Kusonika Ndamba[1], Thierry Tangou Tabou[1]

[1, 2,3]Assistant, [4]Associate Professor, [5]Professor
[1, 2, 3, 4,5]Environmental sciences and management, Faculty of Science and Technology,
[1, 2, 3, 4,5]University of Kinshasa Author, Kinshasa, Democratic Republic of Congo

Abstract: Inappropriate management of this hospital effluent poses a significant risk to public health and the environment, particularly due to the presence of toxic substances and pathogenic germs. This study focused on an area (hospital), which is considered a scourge and a calamity difficult to cure in Kinshasa. The main objective of the study is to evaluate the toxicity of hospital effluents and their impact on health and the environment. This includes the analysis of the physicochemical and microbiological characteristics of effluents in order to understand their potential effects on aquatic ecosystems. Effluent samples were collected and analyzed for their physicochemical and microbiological parameters, as well as for their ecotoxicity. The analyses were carried out in various laboratories using experimental methods, such as the assessment of toxicity for aquatic organisms such as *Gambusia affinis*. The results show that the effluents from the Bondeko Clinic have higher toxicity (LC_{50} = 63 ml/100 ml) than those from the Biamba Hospital (LC_{50} = 87 ml/100 ml). Physicochemical analyses reveal levels of dissolved oxygen, COD, and BOD_5 below the standards recommended by the WHO, as well as a high presence of suspended matter and pathogenic germs. These results highlight a significant risk for the receiving environment and call for measures to manage and treat hospital effluent.

IndexTerms **- Hospital effluent, health risks, ecotoxicological risks.**

I. INTRODUCTION

In the medical sector, the effluents mainly contain chemical substances used in hospitals for healthcare activities and medical research. Although the large quantity of wastewater produced by these establishments allows a significant dilution of the pollutants present, the discharge of these effluents into the municipal sanitation network or into the receiving environment (water, soil, and air) contributes significantly to the overall contamination of the environment, and more specifically aquatic environments.

Indeed, hospital establishments have been recognized as a strong source of emissions of chemical substances into aquatic ecosystems (JouBois et al., 2002).

In addition, wastewater generated by health establishments can be a means of transmission of nosocomial infections. In developed countries, in 2013, the emergence of new infectious diseases contracted during a stay in a Kaja health establishment was noted. Kalambay Rebecca (2021). In many cases, these infections are unavoidable and relatively common. In France, it is estimated that 7% of patients suffer from a nosocomial infection. According to data from other developed countries, the percentage varies from 5 to 12%. The severity of these infections varies and represents a major challenge for public health (Ministry of Health, 2002).

These consequences can be amplified when it comes to so-called special waste, such as wastewater from hospital establishments. According to Colin (2002), in addition to the composition of domestic wastewater, water from sanitation establishments contains more detergents, chemicals, pathogenic microorganisms, parasites, and human debris.

The future of hospital pollutants in the environment and the need to develop sustainable management tools for wastewater from these establishments are questions that raise questions about the various problems caused by liquid discharge from health services. Ecotoxicity studies reveal that hospital waste often presents high toxicity [Leprat (1998), Jehannin (1999), Emmanuel et al. (2001)].

According to Gautier et al. (1996), the results of the ecotoxicity tests Genetic mutation reveals that wastes from clinical

departments and hospital laboratories are genotoxic. The existence of hazardous substances in hospital effluents becomes an interesting research topic due to the discharge of large quantities of hospital wastewater.
In developing countries, such as the Democratic Republic of Congo, poor management of hospital wastewater risks causing disruptions in the functioning of aquatic ecosystems and even contamination of the trophic chain in the receiving environment (water, soil)..

It is in this perspective that lies the interest of this study, which examines the health and ecotoxicological risks of hospital effluents from the city of Kinshasa, in the city province of Kinshasa. Bondeko and Biamba Marie Mutombo hospitals, located in the city province of Kinshasa, are ideal locations to conduct this study due to their importance (300, 200 beds and services, respectively) and their location (close to the Yolo and the Nsanga River).

III. MATERIAL AND METHOD

2.1 **Sampling**

This study was carried out using an experimental approach. The samples were taken between 6 a.m. and 7:30 a.m. at the Biamba Marie Mutombo hospital site and at the Bondeko Clinic, four in number for each, which we coded as follows:

Bondeko clinic:
- CL1 represents the raw effluent at the retention basin;
- CL2 represents the effluent at the discharge point;
- CL3 the sample 100 m upstream at the discharge point;
- CL4 the sample 100 m downstream at the discharge point.

Biamba Marie Mutombo Hospital:
- H1 represents the raw effluent at the retention basin;
- H2 represents the effluent at the discharge point;
- H3 the sample 100 m upstream at the discharge point;
- H4 the sample 100 m downstream at the discharge point.

The samples taken were labeled and kept in a cooler at a temperature of 4 °C and sent to the laboratories for in-depth analyses.

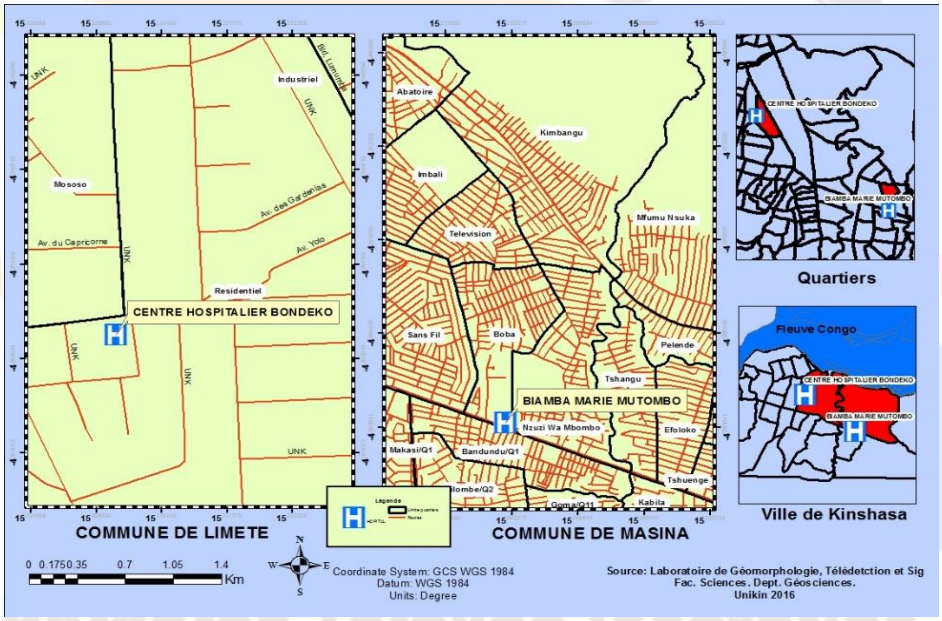


Figure1. Study environment and sampling site.

2.2. Parameter analysis and ecotoxicologist test:

2.2.1 **Physicochemical**

The physicochemical parameters were analyzed in situ and ex situ. In situ, we took temperature, pH, and conductivity using a multi-parameter, and dissolved oxygen using a probe oximeter. Other parameters, in particular BOD, COD, and SS, were analyzed ex situ in the REGIDESO central laboratory according to the methods described by Rodier (2010). The analyses of the different chemical elements (mercury and silver) are carried out using the ***X-ray fluorescence spectrometer***, dispersive energy version (ED-XRF), XEPOS III, a multi-element method in the microbiological laboratory of the General Energy Commission atomic/regional Center for Nuclear Studies of Kinshasa (CGEA/CREN-K).

2.2.2 Bacteriological

As required by the WHO, they first consisted of looking for total fecal coliforms and/or other germs such as fecal streptococci. To achieve this, we have resorted to the technique of sowing in specific cult environments for each germ, in particular PCA (Plat Count Agar) for total germs and Endo Agar for total and fecal coliforms. These media were all prepared according to the technique described by Rodier (2010) and under strict aseptic conditions.

2.2.3 Ecotoxycological test

They consisted of testing the toxicity of the effluents on the bioindicators (*gambusa affinis);* we proceeded as follows:

- Acclimatization of bioindicators (*gambusa affinis*): 30 liters of tap water contained in a basin were exposed to the open air for 24 hours, after the recently caught *gambusa affinis* were placed in this dechlorinated water for 48 hours.
- Preparation of effluents at different concentrations: 4 1-liter cups were used to prepare solutions of concentrations of 100%, 75%, 50%, and 25% with the effluents and dechlorinated water. A 5th was used to contain the control water (100% dechlorinated water). For each concentration, we did three repetitions simultaneously.
- Conduct of the test: we put 3 individuals of *Gambusa affinis* in each concentration and left it in place for 4 days. Every day, monitoring is done to count the number of dead and survivors.
- Calculation of lethal concentration 50 (Cl_{50}) using the Probit method.

IV. RESULTS AND DISCUSSION

4.1. Presentation of results

a. Physicochemical

Table a.1: In situ values of dissolved oxygen in the effluents of Biamba Hospital and Bondeko Clinic and their influencing environments

Samples	DO in mg/l	Average	Standard (WHO, 2O15) in mg/l
H1	1.2	1.05	5-14
H2	1		
H3	1.5		
H4	0.5		
CL1	1.3	1.25	
CL2	1.5		
CL3	1.2		
CL4	1		

Dissolved oxygen values in the different hospital sites are lower than the WHO standard (2015), with an average of 1.05 and 1.25 mg/l at Biamba Hospital and Bondeko Clinic, respectively. , as shown in the table above. These low values result in several dangers and problems for aquatic ecosystems, among others: asphyxiation of aquatic life, reduction of biodiversity, proliferation of species, degradation of water quality, and disruption of biogeochemical cycles.

Table a.2: In situ pH values of effluents from Biamba Hospital and Bondeko Clinic as well as their influence environments

Samples	pH	Average	Standards (WHO, 2012)
H1	6.7	6.9	6.5 – 8.5
H2	7.0		
H3	6.9		
H4	7.0		
CL1	6.9	7.2	
CL2	7.2		
CL3	6.9		
CL4	7.7		

In this table, we see the average pH values of the different sampling sites (6.9 and 7.2), respectively, for Biamba and Bondoko are within the standard range, which indicates that the effluents from the Bondeko clinic and the Biamba hospital do not acidify river water; Yolo and Nsanga, like the latter, have a favorable balanced acidity/basicity level. This means that aquatic organisms (fish, plants, and microorganisms) can develop normally without being affected by too acidic or too basic pH; chemical and biological processes in the water, such as mineral dilution or photosynthesis, take place correctly.

Table a.3: COD values of the tributaries of Biamba Hospital and Bondeko Clinic and their influence environments

Samples	COD (mgO_2/l)	Average	Standards (EU, 2008) in mg O_2/l
H1	150	117.5	125
H2	50		
H3	120		
H4	150		
CL1	150	213.75	
CL2	320		
CL3	85		
CL4	300		

The above result indicates that the COD is high in the sampling sites H1 and H4, with a concentration of 150 mg of O_2/l. This is due to the fact that the effluents from these two sites are loaded with nutrients (organic and mineral materials) whose release into the ecosystem without prior treatment can have serious consequences on aquatic life, biodiversity, and water quality, followed by site H3 with a concentration of 120 mg of O_2/l, and finally H2 with a concentration of 50 mg of O_2/l, with an average of 117.5 mg of O_2/l.
On the other hand, all the clinic's CODs far exceed the standard and hover around 213.75. Exceeding the standard is due to the enrichment of effluents with organic matter.

Table a.4: BOD_5 value of the tributaries of Biamba Hospital and Bondeko Clinic and their influence environments

Samples	BOD_5 (mg O_2/l)	Average	Standards (EU, 2008) in mg O_2/l
H1	47	33.5	≤ 30
H2	24		
H3	13		
H4	50		
CL1	>50		
CL2	>50		
CL3	47		
CL4	>50		

The raw values of the effluent collected in relation to our different environments are 47 and/or greater than 50 mgO2/l in the two institutions; this is justified by the discharge of hospital water loaded with biological fluids from the different services organized in these hospitals. The output values are lower than the standard for Biamba, thus justifying the presence of the step; on the other hand, it remains unchanged at the Bondeko clinic due to the lack of a treatment process.

Table a.5: Turbidity value of effluents from Biamba Hospital and Bondeko Clinic and their influence environments

Samples	Turbidity in NTU	Standards (WHO, 2016) in NTU
H1	22.6	15
H2	17.9	
H3	16.5	
H4	16.5	
CL1	32.7	15
CL2	75	
CL3	18.5	
CL4	20.1	

This table shows that all Turbidity values are high in the different sites of two environments compared to the WHO standard. They are a little more in the sites of the Bondeko clinic, this would be due to the lack of a wastewater treatment plant capable of reducing the mineral pollutant load in suspension

Table a.6: Value of suspended solids in effluents from Biamba Hospital and Bondeko Clinic and their influence environments

Samples	SS (mg/l)	Standards (EU, 2008) in mg/l
H1	530	30mg/l
H2	50	30mg/l
H3	40	
H4	90	
CL1	55	30mg/l
CL2	550	30mg/l
CL3	51	
CL4	55	

This table indicates that the SS levels are high and higher than the EU standard (2008) in all the collection sites for our different samples. This is justified by a high polluting load that comes from the various activities and requires appropriate treatment before release into the environment.

Table a.7: Value of trace metal elements in the tributaries of Biamba Hospital and Bondeko Clinic and their influence environments

Samples	Mercury in mg/kg or ppm	Standards (EU, 2010) in mg/kg	Silver in mg/kg or ppm	Standards (EU, 2010) in mg/kg
H1	< 1.0	0.05	<2.0	0.1
H2	< 1.0		<2.0	
H3	< 1.0		<2.0	
H4	< 1.0		<2.0	
CL1	< 1.0	0.05	<2.0	0.1
CL2	< 1.0		<2.0	
CL3	< 1.0		<2.0	
CL4	< 1.0		<2.0	

This table highlights the presence of Mercury and Silver values in all effluent samples from the Biamba Marie Mutombo Hospital, with a concentration less than 1.0 for Mercury and less than 2.0 for Silver. Their presence is due to the use of Maxima mercury thermometers and the use of developers and fixatives in medical imaging (silver).

Table a.8: Nitrite value of the effluents of Biamba Hospital and Bondeko Clinic and their influence environments

Samples	Nitrite (mg/l)	Standards (AFNOR, 2010) in mg/l
H1	30	10mg/l
H2	20	
H3	90	
H4	90	
CL1	120	10mg/l
CL2	210	
CL3	110	
CL4	100	

This table indicates that the nitrite values measured for the different samples present concentrations higher than the AFNOR 2010 standard of 10 mg/dl, which could have negative impacts on the environment in the event of release without prior treatment. These results underline the need to implement effective depollution systems to reduce nitrite levels before discharging hospital effluent into the environment.

b. Bacteriological

Table b1: Count of microorganisms (total germs, total coliforms and fecal coliforms) in samples from Biamba Hospital and Bondeko Clinic

Samples	TG (cfu /l)*10^6	TC (cfu /l)*10^6	FC (cfu /l)*10^6
H1	1080	184	28
H2	500	10	2
H3	910	292	67
H4	1240	412	174
CL1	1870	732	8
CL2	640	39	3
CL3	250	43	6
CL4	1510	46	13

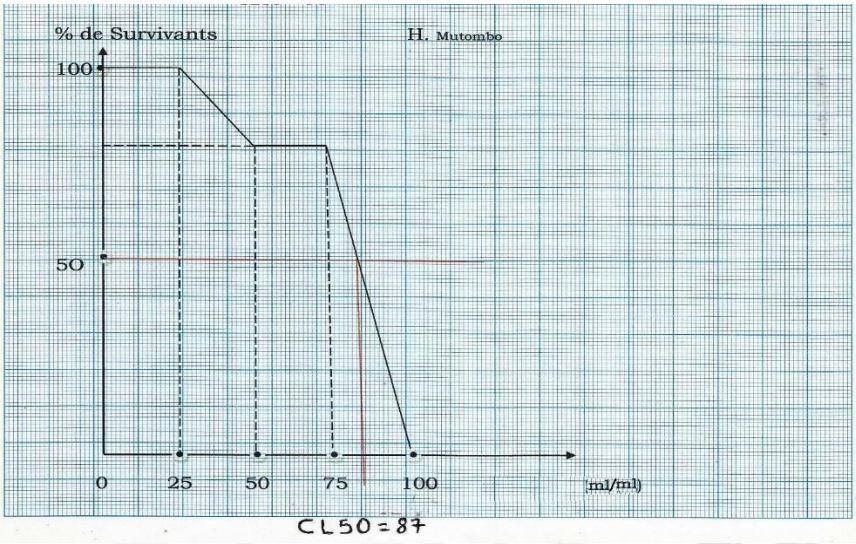
From this table, it is evident that all samples contain total germs (TG), total coliforms (TC), and fecal coliforms (FC). This situation is linked to the fact that hospital effluents are naturally rich in various microorganisms resulting from activities carried out in different departments.

c. Ecotoxicological

Table c.1: Number and percentage of survivors of *Gambusia affins* in the hospital effluent of the Biamba Hospital

Effluents	Dilutions	Death Number				Number of deaths	% survivor
		1st day	2nd day	3rd day	4th day		
100ml	0ml	1	1	1	0	3	0
75ml	25ml	0	1	0	0	1	66.7
50ml	50ml	0	1	0	0	1	66.7
25ml	75ml	0	0	0	0	0	100
T	100ml	0	0	0	0	0	100

The populations of Gambusia are very exposed to hospital effluent from Biamba Marie Mutombo. In the 100-mL concentration there is 0% survivors, while in the 75-mL and 50-mL concentrations there are 66.7% survivors. This demonstrates that effluents released without treatment or dilution of more than 50% contains substances toxic to the environment.



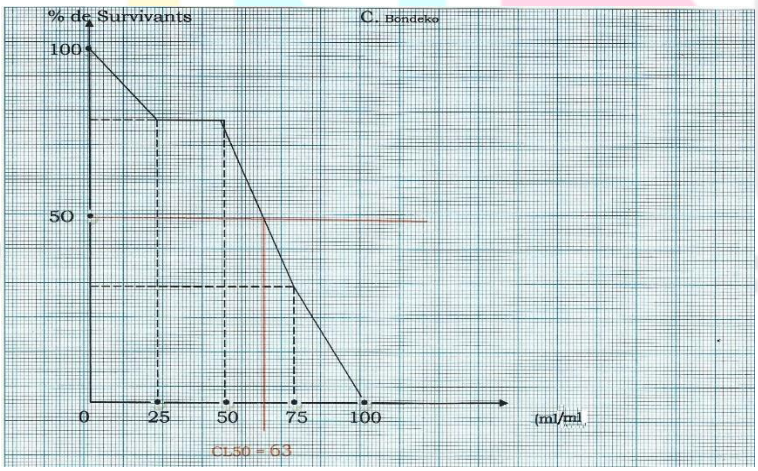
Graphic1. Curve of survivors of *Gambusia affinis* at the effluent of the Biamba Mutombo Hospital and calculation of LC_{50}.

Based on this graphic, we can estimate that the volume of effluent from Biamba Hospital Mutombo, which is effective and capable of killing 50% of Gambusia affinis individuals, is approximately 87 ml.

Table c.2: Number and percentage of survivors of *Gambusia affins* in the hospital effluent of the Bondeko Clinical Hospital

Solution	Death number				Number of deaths	% survivor
	1st day	2nd day	3rd day	4th day		
100	3	-	-	-	3	0
75	1	1	0	0	2	33.3
50	0	0	1	0	1	66.7
25	0	0	1	0	1	66.7
T	0	0	0	0	0	100

Populations of Gambusia affinis are extremely exposed to hospital effluent from Clinique Bondeko. At a concentration of 100 mL, there are 0% survivors from the first day of contact, followed by the concentration of 75 mL, which represents 33.3%, and the concentrations of 50 mL and 25 mL each represent 66.7% of survivors.



Graphic2: *Gambusia affinis* survivor curve at the Bondeko Clinic effluent and calculation of LC_{50}

From this graphic, it appears that the volume of the effluent from the Bondeko Clinic is toxic to the test individuals and capable of killing 50% of the populations of exposed *Gambusia affinis* individuals is around 63 ml.

4.2. DISCUSSION

The results of physicochemical analyses indicate that the waters of these two hospital establishments have levels of dissolved oxygen lower than the WHO standard (2005) set at 4–11 mg/l. The accumulation of organic matter and the increase in temperature in these effluents could explain these decreases. According to our conclusions, the presence of organic matter in a watercourse leads to oxygen consumption (therefore a reduction in dissolved oxygen). These results are much lower than those of Kaja (2022). The pH values of the different sampling sites in each health facility meet WHO standards (2012).

The different COD values of the different hospital samples and their context of influence indicate a range of values higher than the EU standard (Op.cit.), which is set at 1125mg/L. However, those of the Bondeko clique are higher than those of BIAMBA hospital. The presence of chemicals in hospital effluent, such as detergents and other products, could be explained by this situation. These results remain lower than those of Kaja (2022).

The BOD_5 levels observed in the effluents of the Biamba Hospital and its surrounding environment exceeded the EU standard (2008), which was 25 mgO_2/l. In particular, the values of the H4 (50 mgO2/l) and H1 (47 mgO2/l) sites were higher, which could be explained by the presence of organic matter in the raw effluent (H1) and diffuse pollution downstream, at the point of discharge. The effluent from the BONDEKO Clinic continues to be catastrophic, with higher values in the sampling sites due to the significant quantities of organic matter and the lack of a WWTP.

The different samples present turbidity higher than the standard established by the WHO (2003), which demonstrates that there is no effective treatment and very logically influences the SS values. High levels of suspended solids were observed in the raw effluent of the Biamba Hospital (530 mg/l) at the entrance and at the discharge point of the Bondeko Clinic (550 mg/l), which proves the efficiency of the purification system put in place by the hospital and the lack of STEP in Bondeko.
The search for metallic trace elements in samples from the Biamba hospital and the Bondeko clinic revealed the presence of mercury and silver. These values would be due to the use of Maxima mercury thermometers and the use of developers and fixatives in medical imaging (silver).

The BONDEKO clinic has very high nitrite levels, with extreme values such as 110 mg/l (CL3) and 210 mg/l (CL2) compared to the AFNOR standard (2010). The clinic would be responsible for this situation by using food products of plant origin. These conclusions corroborate those of Kitambala et al. (2016), who studied the subject. Data on nitrites from hospital effluents from Biamba Hospital Mutombo are within the range of the AFNOR standard (Op.Cit.) set at 50 mg/l. The high values are generally in the H3 and H4 sites, i.e., 90 mg/l for each site. The pollution at the H3 and H4 sites would be due to other sources of pollution (diffuse pollution).

Bacteriologically, all samples contain total germs (TG), total coliforms (TC), and fecal coliforms (FC) in quantities of the order of millions of colonies per liter. This situation is linked to the fact that hospital effluents are naturally rich in various microorganisms resulting from activities carried out in different departments.

ecotoxicological information regarding the lethal concentration 50 (LC_{50}), it is obvious that the effluents from the BONDEKO clinic are extremely toxic compared to the effluents from the Biamba Marie Mutombo Hospital, with a LC_{50} of approximately 63 ml/100 ml rather than 87 ml/100 ml. This could be attributed to the use of detergents, disinfectants, drug residues, and other solutions or chemicals toxic to the receiving environment without preparation. These results are in agreement with those of Boillot et al. (2005), who studied the ecotoxicological characterization of hospital effluents.

CONCLUSION AND RECOMMENDATIONS

The aim pursued in this study was to evaluate the toxicity of hospital effluents and their impact on health and the environment. At the ends of this work on “Evaluation of health and ecotoxicological risks of hospital effluents from Biamba Hospital Marie Mutombo and Clinique Bondeko in Kinshasa," it emerges:

On a physicochemical and microbiological level, the high levels of contamination detected in the effluents of the Bondeko clinic explain the harmful effect on the receiving environment, in particular the presence of pathogenic germs and the occurrence of various diseases.
The particularities of these various samples lie in their contamination by toxic pollutants, such as mercury and silver (non-biodegradable products or heavy metals).

Ecotoxicological analyses reveal the toxicity of the effluents from the Bondeko Clinics compared to those from the Biamba Marie Mutombo hospitals because the latter has an additional wastewater treatment plant.

In order to prevent any pollution from hospital effluents.

- Filter effluents in order to reduce the pollutant load (SS);
- Pretreat via natural lagooning processes preceded by an anaerobic pond in order to reduce hard COD;
- Apply the polluter pays principle in relation to the degree of toxicity of hospital effluents.
- Apply or use the principles of hospital effluent monitoring.

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