PRESENT STATUS OF ENVIROMENTAL APPLICATION OF ELECTRON BEAM ACCELERATOR IN BRAZIL

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INTRODUCTION

- **The effluent generate by the industries in São Paulo are one of the main causes for the environmental pollution.**

- **Most of these contaminants biodegrade very slowly, becoming dangerous for men, plants and animals.**

- **The conventional treatment and available technologies to treat such waste have low efficiency.**

- **The industries are searching for alternative technologies to degrade chemical compounds to get a better quality of effluent and consequently improve the environmental conditions.**

Advanced Oxidation Process (AOP)

The oxidation processes with OH radicals are the most efficient to mineralize organic compounds, and there are various methods to generate OH radicals as the use of ozone, hydrogen peroxide, ultra-violet radiation and ionizing radiation.

OBJECTIVE

This paper presents the evaluation of the efficiency of ionizing radiation treatment of actual effluents and samples from different origin, distinct physical chemical characteristics and organic compound concentrations, such as drinking water, wastewater treatment plant, industrial, and petroleum production.

1. Drinking water treatment

In part of the year, mainly in the summer time, it is possible to note alterations in the taste and odor of public drinking waters distributed in São Paulo City.

The main responsible organic composites for the taste and odor type earth and mould of surface waters are Geosmin (*trans*-1, 10-dimethyl-*trans*-decalol) and 2-methylisoborneol, these compounds are produced by several species of cyanobacteria (blue-green algae)

It is extremely difficult to degrade microbiologically and conventional treatment processes of surface water are not effective in removing or destroying these toxins, procedures using activated charcoal are effective for low concentrations.

2. Effluent from Wastewater Treatment Plant

The Suzano Wastewater Treatment Plant (WTP) has a processing capacity of 1.5m^3/s, receiving domestic and industrial wastewater from five different cities. About 50% of wastewater in this plant are from chemical, pharmaceutical, textile and dyes industries origin .

Five steps of the conventional treatment of the WTP were selected for sampling: Industrial Receiver Unit influent (IRU), Coarse Bar Screens effluent (CBS), Medium Bar Screens effluent (MBS), Primary Sedimentation effluent (PS) and Final Effluent (FE).

3. Effluent from industrial complex

Industrial complex composed by eight separated production units named:

Intermediary Organic Products (IOP), Poly Vinyl Acetate (PVA), Resins (RES), Special Products (SP), Detergents (DET), Sulphonation (SULF), Thiodan (THIO) and Azo dyes (AZO).

Each unit delivered its effluent to the small treatment station, where they were mixed and the pH was neutralized (5 samples from the mixed effluent, ME1 to ME5).

4. Effluent from Petroleum Production

During the offshore oil production large volumes of aqueous waste with high salinity are produced.

This water is normally separated from oil on the platform generating aqueous effluent with metals, sulfite, ammonium and organic compounds.

The conventional treatment used includes filtration, flotation, ionic change and adsorption in activated charcoal, but the high salinity of this water decreases the efficiency of these treatments.

PROCESSING

Drinking Water Treatment, Alto Boa Vista – SABESP

- Gamma irradiation Co-60 source (Gammacell, 11,000 Ci) in a batch system.

Wastewater Treatment Plant and Effluent from Petroleum Production

- Electron Beam Facility with a 1.5 MeV Dynamitron from Radiation Dynamics Inc.
- Irradiation performed in a batch system using Pyrex glass.

Effluent from Industrial Chemical Complex

- Electron Beam Facility with a 1.5 MeV Dynamitron from Radiation Dynamics Inc., using Electron Beam Pilot Plant
- The sample stream had a medium flow rate of 30L/min; the electron beam with 1.5MeV energy and the current was varied from 1.2mA to 10.6mA in order to obtain the desired doses

CHEMICAL ANALYSIS

To physical chemical characterization of the samples were performed according to the Standard Methods for the Examination of Water and Wastewater.

Analyses of Total Organic Carbon (TOC) were performed using Total Organic Carbon Analyzer, Shimadzu, model TOC 5000A.

The qualitative and quantitative analysis of organic compounds were performed by mass spectrometry using the Gas Chromatograph associated to Mass Spectrometer Shimadzu model GCMS-QP 5000.

RESULTS

Drinking Water

Table 1. Variation on the odorific organic compounds with applied doses in water samples from Guarapiranga reservoir

DOSE (kGy)	Without tratment		After decantation		Final Water	
	GEOSMIN ($ng.L^{-1}$)					
0.0	860	160	960	88	800	88
0.5	106	120	134	<4	70	<4
1.0	40	35	20	<4	10	<4
2.0	18	<4	<4	<4	<4	<4
3.0	13	<4	<4	<4	<4	<4
	METHILISOBORNEOL ($ng.L^{-1}$)					
0.0	900	93	1130	89	930	45
0.5	194	15	204	<4	206	<4
1.0	56	13	56	<4	50	<4
2.0	22	7	<4	<4	<4	<4
3.0	5,6	<4	<4	<4	<4	<4

RESULTS

Drinking Water

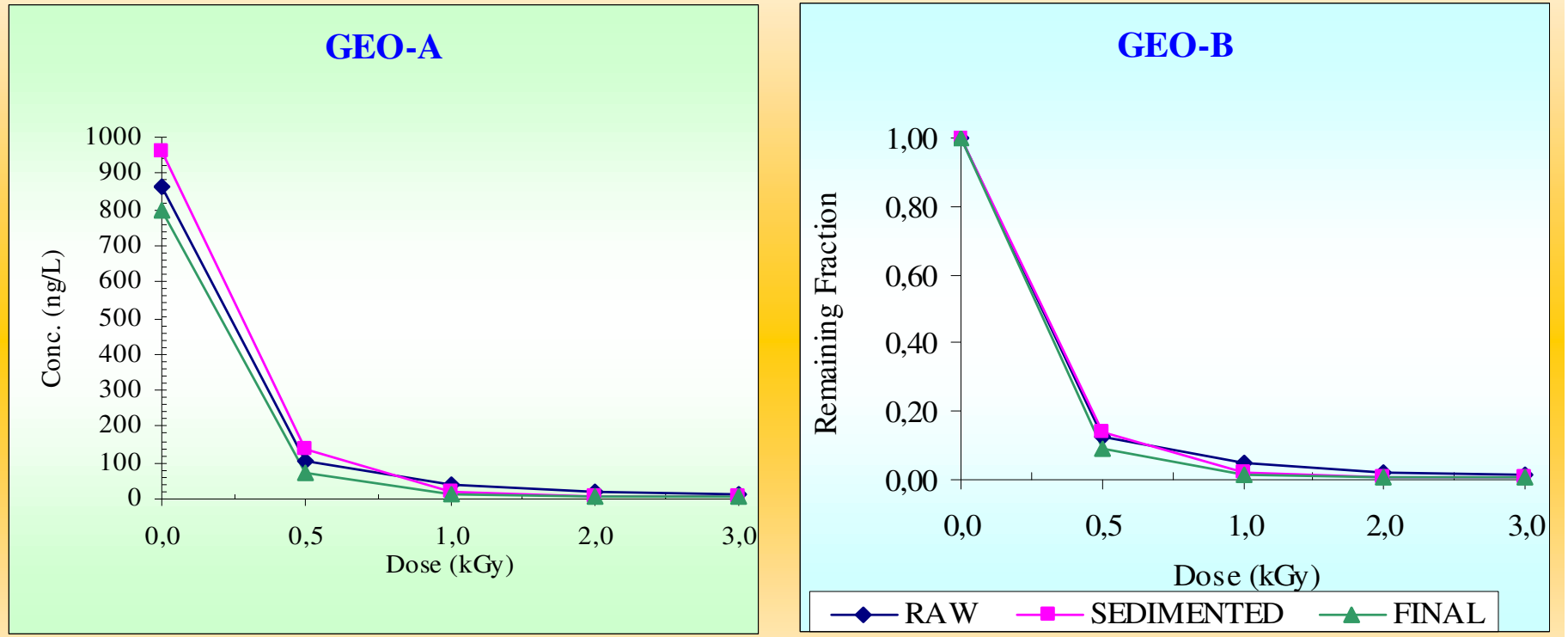


Figure 1. Removal of geosmin from three kinds of water samples at different applied doses, concentration by dose (a) and remaining fraction by dose (b).

RESULTS

Drinking Water

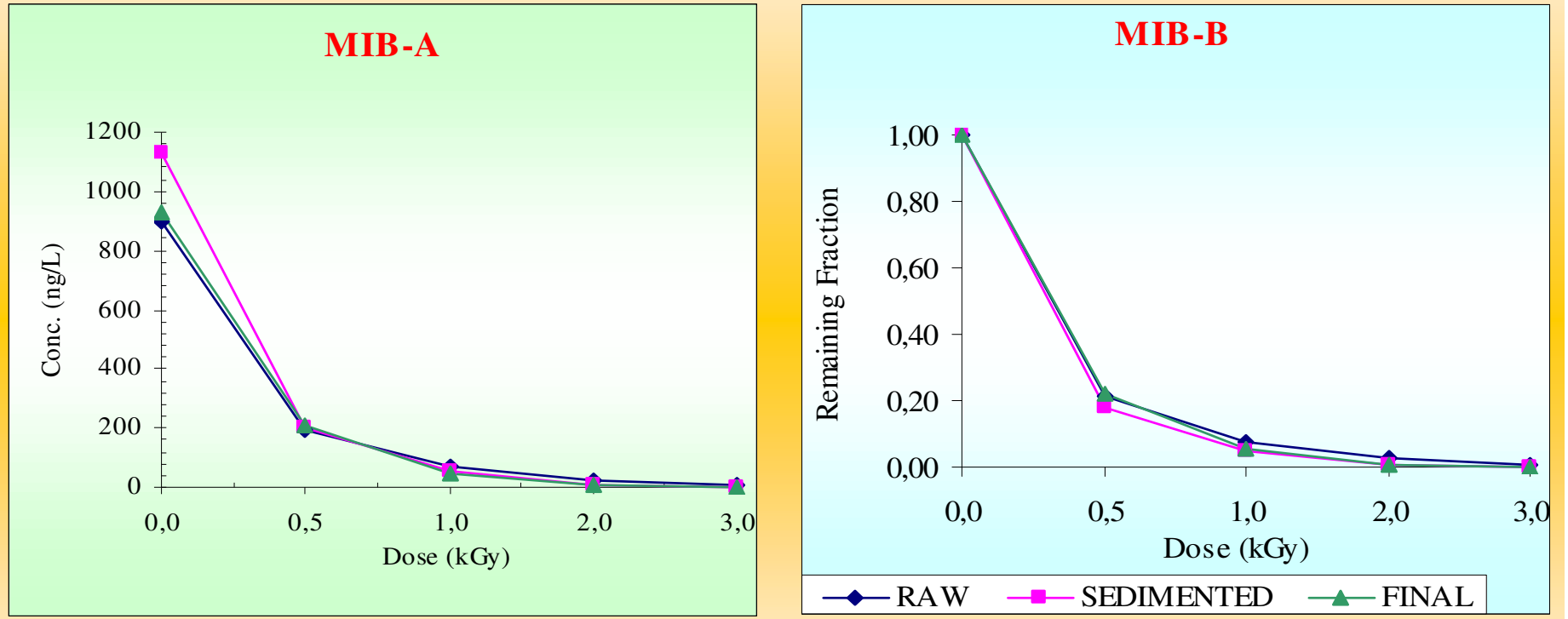


Figure 2. Removal of 2-methylisoborneol from three kinds of water samples at different applied doses, concentration by dose (a) and remaining fraction by dose (b)

RESULTS

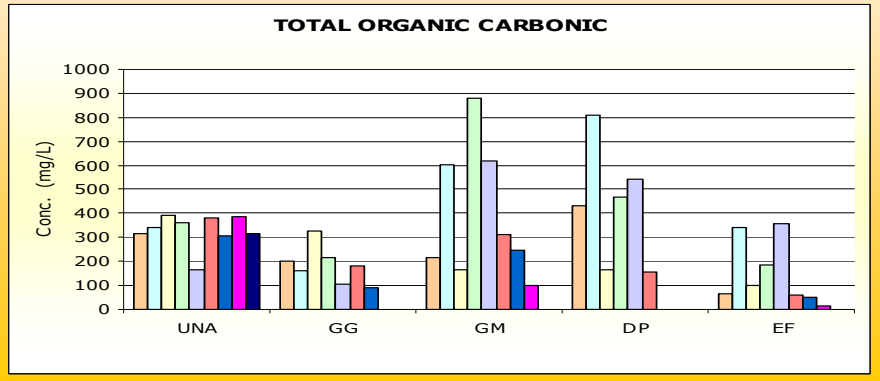
Wastewater Treatment Plant

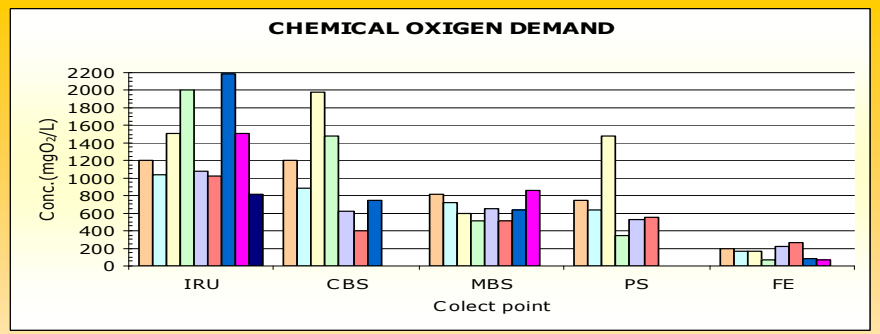
TABLE II - Average of the physical chemical parameters in different steps of WTP

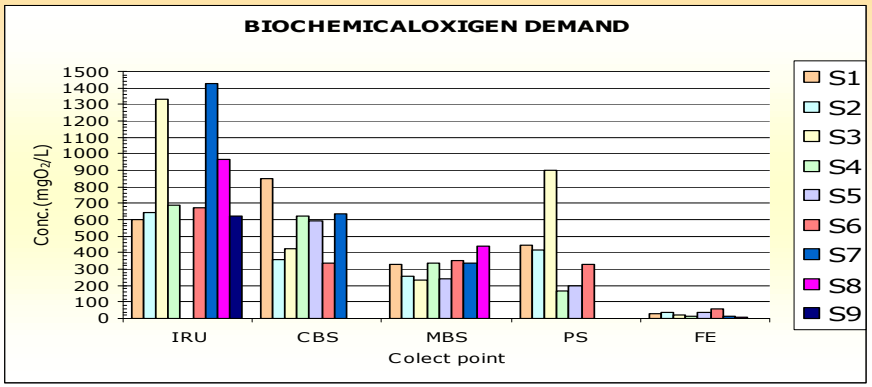
SAMPLE	COD (mgO_2/L)	BOD (mgO_2/L)	TOC (mg/L)	Total Solid (mg/L)	T. Volatile Solid (mg/L)	pH
IRU	1362 ±445	854 ±318	330 ±74	3599 ±982	624± 237	8.3 ±0.3
CBS	1044 ±547	545 ±183	212±79	2648 ±1025	552±224	7.4 ±0.2
MBS	663 ±126	315 ±68	465 ±278	2691 ±690	583 ±328	7.5 ±0.4
PS	713 ± 396	410 ±266	428 ±245	1333 ±377	450 ±284	7.8 ± 0.5
FE	153 ±56	28 ±15	185 ±133	632 ±372	203 ±109	7.8 ±0.4

RESULTS

Physical chemical characterization of the samples from WTP







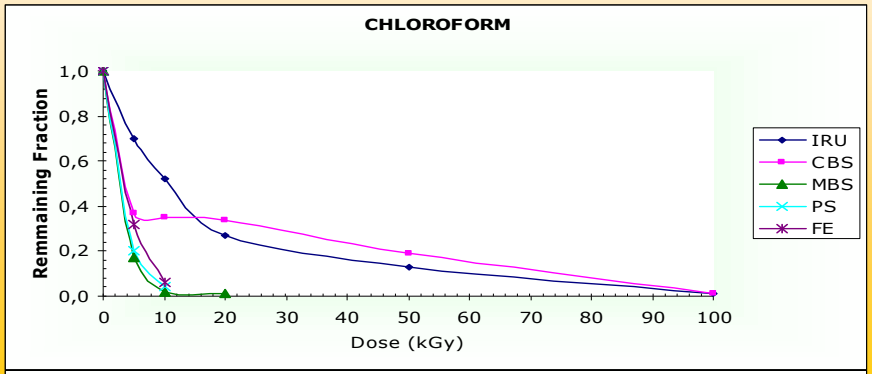
Wastewater Treatment Plant

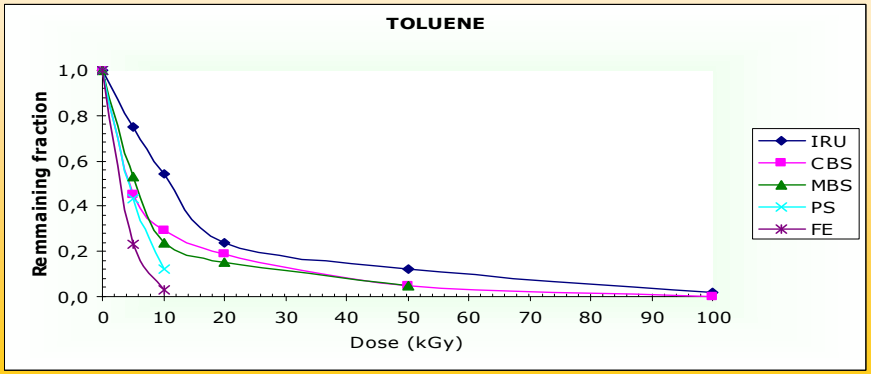
TABLE III - Minimum and maximum concentration of the main organic compounds present in steps of WTP

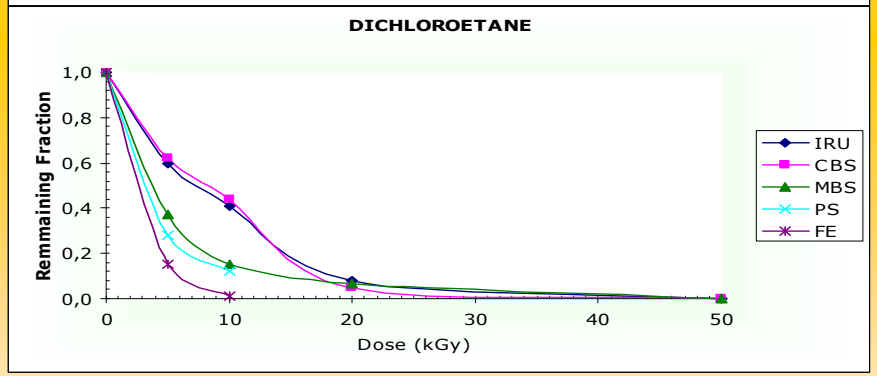
ORGANIC COMPOUNDS	IRU	CBS	MBS	PS	FE
	Concentration (mg/L)				
Methylisobutyl keton	1.00 - 22.30 *(20)*	1.30 - 7.85 *(20)*	0.22 - 3.52 *(20)*	0.98 - 2.69 *(10)*	<dl
Dichoroethane	1.30 - 25.70 *(20)*	1.10 - 16.00 *(20)*	1.86 - 5.58 *(20)*	0.98 - 3.69 *(10)*	0.40 - 1.85 *(10)*
Toluene	0.80 - 12.00 *(50)*	1.00 - 72.00 *(50)*	0.51 - 2.57 *(20)*	0.85 - 1.60 *(10)*	0.32 - 1.97 *(10)*
Xylene	1.50 - 67.00 *(50)*	0.50 - 25.70 *(50)*	1.22 - 3.51 *(20)*	0.96 - 1.82 *(10)*	0.12 - 4.00 *(10)*
Phenol	3.20 - 7.80 *(50)*	3.20 - 16.40 *(50)*	0.96 - 2.00 *(20)*	0.86 - 1.60 *(10)*	0.50 - 0.86 *(10)*

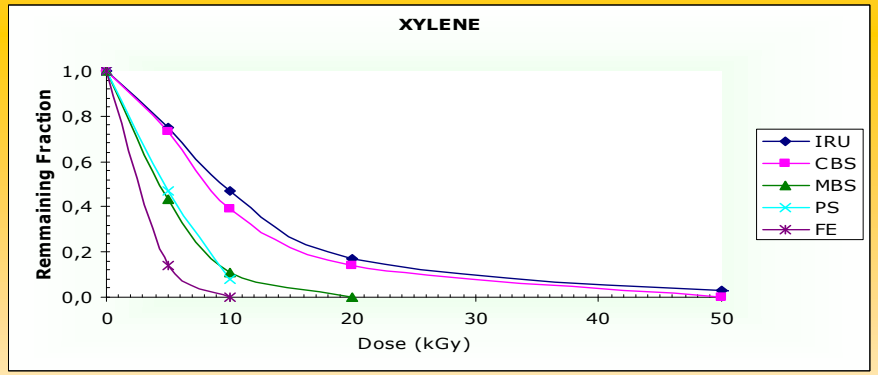
dl = detection limit = 0.03 mg/L
Variation = 10%
() Necessary Absorbed Dose to 90% removal

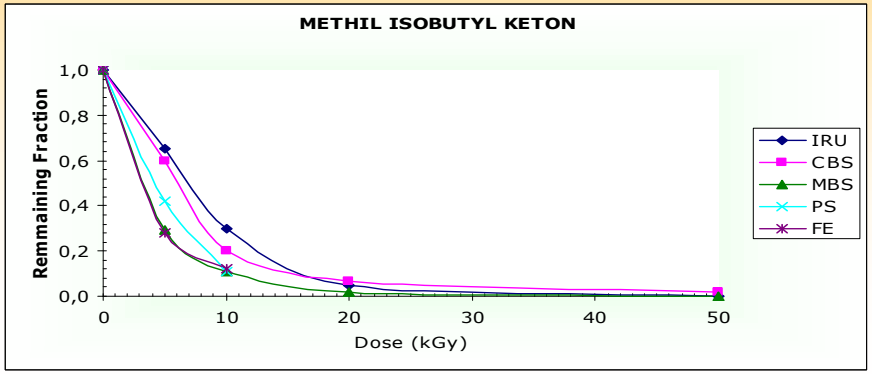
Organic compounds removal after electron beam irradiation of samples from WTP

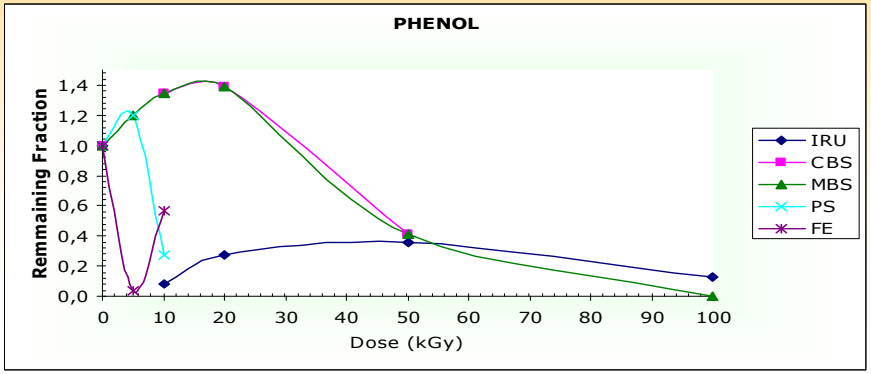












Industrial Complex Effluent

TABLE IV – Physical chemical characterization of industrial effluent

SAMPLE	pH	COD (mgO_2/L)	SULFATES (mg/L)	OIL & GREASE (mg/L)	SUSPENDED SOLIDS (mg/L)
MIXED EFFLUENT (ME)					
ME 1	9.60	951.00	584.0	100	182
ME 2	7.83	1,73	482.0	na	353
ME 3	8.12	1,25	352.0	na	254
ME 4	8.29	na	na	na	151
ME 5	7.93	2,31	1,6	21	181
SEPARATED UNITS					
POI	1.40	8,34	18,1	43	92
PVA	4.17	2,52	250.0	65	110
RESINS	12.20	1,61	117.0	279	118
SPECIALPRODUCTS	6.72	2,91	70.0	78	276
DETERGENTS	7.61	29,00	302.0	285	268
SULFONATION	6.66	1,32	110.0	94	58
THIODAN	7.54	466.00	233.0	69	64
AZODYES	12.80	1,84	22,8	56	494

Na=not analyzed

Industrial Complex Effluent

TABLE VI – Organic Compounds concentration in the effluent from industrial complex

Sample	**Dichloroethane** (mg/L)	**Methyl isobutyl ketone** (mg/L)	**Benzene** (mg/L)	**Toluene** (mg/L)	**Xylene** (mg/L)	**Phenol** (mg/L)
ME1	87.9 *(20)*	na	*	6.3 *(20)*	9.3 *(15)*	2.8 *(50)*
ME2	2.6 *(20)*	na	*	1.1 *(20)*	1.5 *(20)*	3.2 *(50)*
ME3	0.2 *(20)*	na	*	1.8 *(20)*	0.1 *(20)*	0.1 *(50)*
ME4	51.3 *(20)*	24.2 *(20)*	*	13.1 *(20)*	24.3 *(30)*	2.3 *(50)*
ME5	65.7 *(30)*	34.0 *(20)*	*	25.3 *(10)*	27.2 *(10)*	1.9 *(50)*
RES	<0.010	na	<0.10	<0.10	0.6 *(50)*	0.6 *(50)*
PVA	<0.010	na	6.2 *(50)*	<0.10	1.6 *(50)*	1.6 *(50)*
DET	<0.010	na	0.3 *(50)*	<0.10	1.9 *(50)*	1.9 *(50)*
POI	<0.010	na	0.3 *(50)*	0.2 *(50)*	1.1 *(50)*	1.1 *(50)*
SULF	28.4 *(50)*	na	<0.10	<0.10	0.6 *(50)*	0.6 *(50)*
THIO	0.1 *(50)*	na	<0.10	<0.10	<0.10	<0.10
AZO	1.8 *(30)*	na	<0.10	<0.10	0.4 *(50)*	0.4 *(50)*

() Necessary Absorbed Dose to 90% removal

* = Under the detection limit

RESULTS

TABLE V - Chemical characterization of the studied petroleum effluent

SAMPLE	TOC (mg/L)	SULFITE (mg/L)	AMMONIUM (mg/L)	pH
PRODUCTION UNIT A				
SA1	450.2	na	na	9.88
SA2	478.5	0.3	1500.0	9.45
SA3	582.0	0.2	307.4	9.54
SA4	427.7	1.7	2817.0	9.28
PRODUCTION UNIT B				
SB1	142.8	Na	na	8.01
SB2	135.7	11.2	182.5	7.89
SB3	217.2	28.8	72.0	8.07
SB4	491.5	91.3	64.9	7.88

Standard Deviation: pH = ± 5% TOC = ± 10%

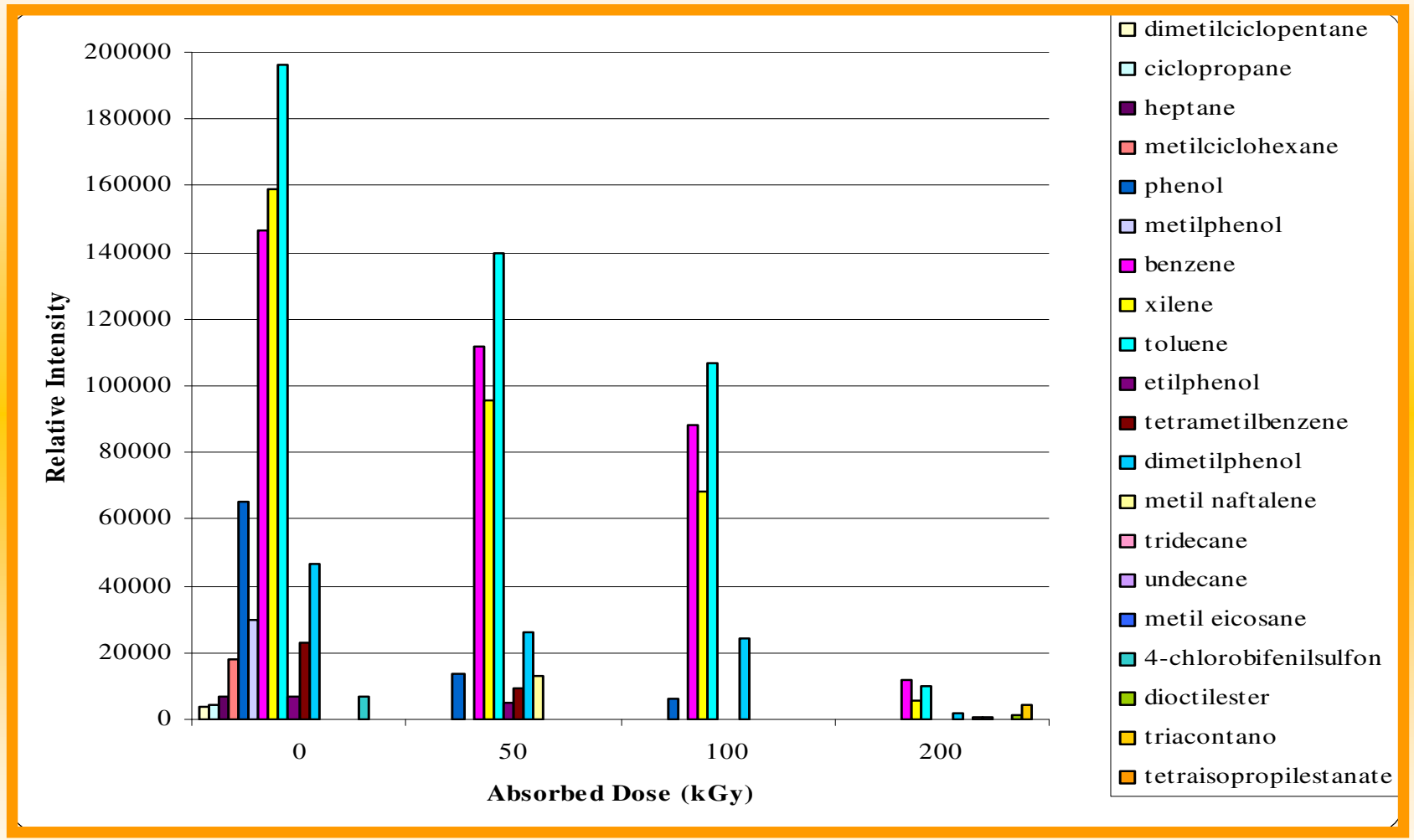
RESULTS

TABLE VI – Organic Compounds concentration in the effluent from and petroleum production

Sample	Benzene (mg/L)	Toluene (mg/L)	Xylene (mg/L)	Phenol (mg/L)
SA1	99,30 (100)	134,49 (100)	307,00 (100)	4,24 (50)
SA2	146,80 (100)	218,22 (100)	585,06 (50)	3,27 (50)
SA3	119,79 (100)	195,36 (100)	333,44 (100)	1,47 (50)
SA4	111,71 (100)	216,93 (100)	243,24 (50)	1,39 (50)
SB1	22,46 (20)	8,53 (20)	6,61 (20)	3,73 (20)
SB2	42,17 (50)	27,12 (50)	24,40 (50)	1,92 (20)
SB3	35,30 (20)	20,83 (20)	12,65 (20)	1,65 (20)
SB4	49,05 (20)	27,33 (20)	17,70 (20)	0,98 (20)

() Necessary Absorbed Dose to 90% removal

RESULTS



Main organic compounds in the petroleum production effluent and their removal after e-beam irradiation with different absorbed doses

TABLE VII- Obtained Gd x 10^3 (mol/J) values for main organic compounds in the effluent

Sample	Dichloroethane	Methyl isobutyl ketone	Benzene	Toluene	Xylene	Phenol
WASTEWATER TREATMENT PLANT						
RUI	33.9	25.6	*	15.0	51.6	5.2
CBS	36.4	17.6	*	69.4	29.5	10.7
MBS	27. 1	14.0	*	8.0	9.7	4.8
PS	23.1	9.2	*	7.9	4.8	4.9
FE	11.1	*	*	10.2	19.5	11.0
INDUSTRIAL COMPLEX EFFLUENT						
ME1	288.9	*	*	38.3	391.0	2.6
ME2	18.5	*	*	14.2	18.2	0.0
ME3	1.0	*	*	6.4	0.6	-0.6
ME4	226.8	101.7	*	64.8	42.2	4.6
ME5	265.1	150.0	*	256.2	121.0	3.7
RES	*	*	*	10.8	*	-3.4
PVA	*	*	*	0.5	*	1.4
DET	*	*	*	0.1	0.5	1.0
POI	20.0	*	*	*	*	1.0
SULF	0.4	*	*	*	*	*
THIO	4.6	*	*	*	*	0.5
AZO	35.2	*	*	5.91	74.3	-3.4

TABLE VII- Obtained Gd x 10^3 (mol/J) values for main organic compounds in the effluent

Sample	Dichloroethane	Methyl isobutyl ketone	Benzene	Toluene	Xylene	Phenol
PETROLEUM PRODUCTION						
SA1	*	*	121,2	132,9	302,4	8,7
SA2	*	*	179,1	214,7	1152,4	6,7
SA3	*	*	145,2	384,1	327,9	3,0
SA4	*	*	135,4	212,7	478,7	2,8
SB1	*	*	137,0	42,0	32,5	7,7
SB2	*	*	102,9	53,4	48,1	3,9
SB3	*	*	215,3	102,4	62,3	3,4
SB4	*	*	299,2	134,4	87,2	5,0

* Under the detection limit

RESULTS


ME4
ME4 10 kGy
ME4 20 kGy
ME4 50 kGy
ME4 100 kGy
ME4 200 kGy


SSEB 4
SSEB 4 20 kGy
SSEB 4 50 kGy
SSEB 4 100 kGy
SSEB 4 200 kGy


SSEB 5
SSEB 5 20 kGy
SSEB 5 50 kGy
SSEB 5 100 kGy
SSEB 5 200 kGy


RIO 1
RIO 1 20 kGy
RIO 1 50 kGy
RIO 1 100 kGy
RIO 1 200 kGy

CONCLUSION

- **The electron beam processing has shown high effectiveness in removing organic compounds in complex effluents. In terms of yield *Gd* (Mol/J), the process showed more effectiveness when the number of organic molecules increase, because the reaction among reactive transients produces more free radicals continuing the process.**

- **Besides the high necessary absorbed doses, it is a promising process for future field implementation, because the high complexity of the effluent become its treatment by others technologies very expensive and not so efficient, but it is necessary to combine with conventional treatments such as biological.**

- **For implementation in Brazil, it was detect the necessity of building a mobile system to disposal this new technology to industries and governmental installation's.**


IAEA-INTERNATIONAL SYMPOSIUM ON UTILIZATION OF ACCELERATORS
DUBROVNIK-CROATIA
Acknowledgements
To IAEA for financial support
Thank you very much !
CELINA LOPES DUARTE
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