# ELECTRON BEAM TREATMENT AS A FUTURE ECO-TECHNOLOGY FOR MICROPLASTICS REMOVAL IMPROVEMENT IN WASTEWATER AND SEWAGE SLUDGE

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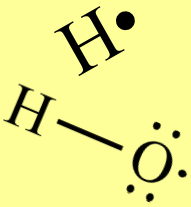
## I. THE MECHANISM OF THE ELECTRON BEAM ACTION

**DIRECT:** damage to DNA and RNA

**INDIRECT:** production of large quantities of reactive species



$H_2O \rightarrow OH\bullet + e^-_{aq} + H\bullet + H_3O^+ + H_2 + H_2O_2$

**Oxidising agent:** $E°(OH\bullet/H_2O) = +2.72V$

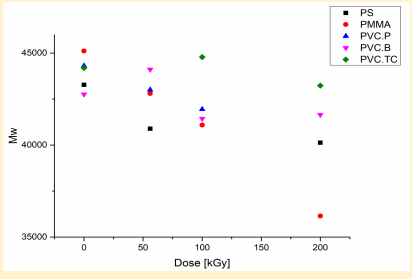
**Reducing agents:** $E°(H_2O/e^-_{aq}) = -2.9V$ and $E°(H^+/H\bullet) = -2.3V$

**Table 1** G values of water radiolysis products at pH 1 and 10

| Number of molecules, atoms or free radicals per 100eV of energy absorbed (G value) | pH | Water radiolysis products | | |
|---|---|---|---|---|
| | | OH• | $e^-_{aq}$ | H• |
| | 1 | 2.9 | 0 | 3.6 |
| | 10 | 2.8 | 2.7 | 0.4 |

## II. POLYMER STRUCTURE CHANGES

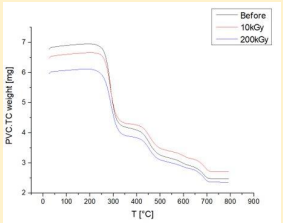
### Molecular Weight Decrease




Polymer molecular weight inversely proportional to irradiation dose

**Fig. 1** Molecular weight of various plastics irradiated at 0 to 200kGys, APC (Acquity, Waters), THF, concentration of samples 0.5 – 10 mg/mL

### Thermal stability changes



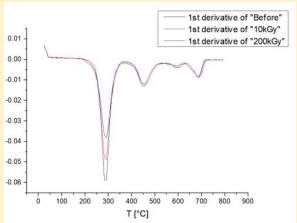




**Fig. 2.** TGA measurement of PVC tablecloth samples before and after the irradiation at 10, 200 kGy, Mettler TGA 1, 10K/min, nitrogen atm (left) and its derivative (right)

## III. MICROPLASTICS SEDIMENTATION PROPERTIES IMPROVEMENT

### Induced plastic sedimentation

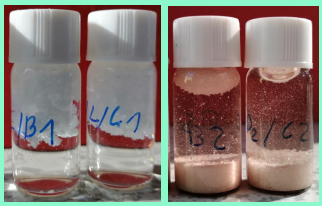


**Fig. 3.** Pictures of the PS plastic before (left) and after (right) the EB treatment in tap water

### Density increase

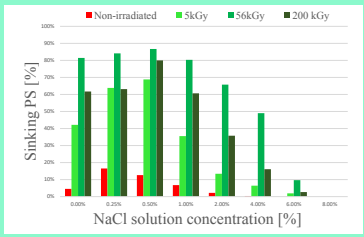
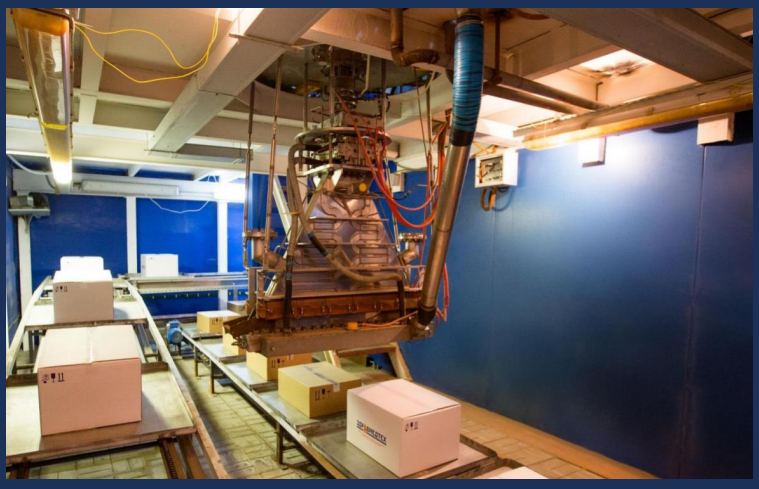



**Fig. 4.** Percentage of sinking PS plastic before (red) and after (green) the EB treatment, testing in NaCl, water-based solution

87% of sinking PS plastic after the irradiation at 56kGy compared to 13% of non-treated sample



## IV. MICROPLASTICS DEGRADATION

### Partial plasticizer removal

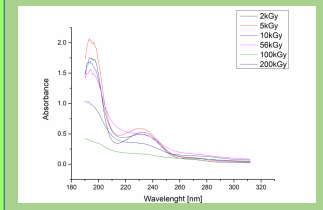



**Fig. 5.** UV-VIS spectrum of the DEHP plasticizer removed from the PVC plastic after the treatment in tap water, METTLER UV 5

### Plastics mass loss

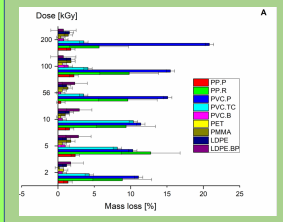



**Fig. 6** Mass loss in plastics irradiated at various doses (2-200kGy) in tap water

### Plastic yellowing

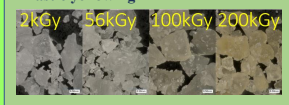



**Fig. 7.** Pictures of the PVC treated at various doses, x100, VHX 2000 Keyence

### Plastics discolouration


**Fig. 8.** Pictures of the PET (left) and PMMA (right) before (top) and after (bottom) the treatment, x100, VHX 2000 Keyence

## V. CONCLUSIONS

Electron beam treatment is a potential future tool for ecological, risk-free treatment of contamination in wastewater and sewage sludge, capable of microplastics modifications, removal (by coagulation and sedimentation) efficiency improvement and plasticizer extraction.

[1]"NJ woman infected with E. coli sues over Romaine lettuce." [Online]. Available: https://eu.app.com/story/news/health/2018/04/16/e-coli-romaine-nj-lawsuit/520641002/. [Accessed: 15-Nov-2019]. [2]"Ascariasis: Causes, symptoms, and treatment." [Online]. Available: https://www.medicalnewstoday.com/articles/322340.php#what-is-ascariasis. [Accessed: 18-Nov-2019]. [3] "Researchers tackle biofilm to make salmonella infection less aggressive | The Times of Israel." [Online]. Available: https://www.timesofisrael.com/researchers-tackle-biofilm-to-make-salmonella-infection-less-aggressive/. [Accessed: 15-Nov-2019]. [4]Y. Kim, B. Han, J. K. Kim, N. Ben Yaacov, and K. Y. Jeong, "Design of Electron Beam Sludge Hygienization Plant," *Int. Top. Meet. Nucl. Res. Appl. Util. Accel. Vienna*, 2009 [5]T. D. Waite, C. N. Kurucz, W. J. Cooper, D. Brown, and C. Gables, "Full Scale Electron Beam Systems for Treatment of Water , Wastewater and Medical Waste," in *IAEA-SM-350/54*, 1985, pp. 187–201.[6]"China approves its first irradiation system to treat polluted water - People's Daily Online." [Online]. Available: http://en.people.cn/n3/2017/1123/c90000-9296321.html. [Accessed: 15-Nov-2019].[7]J. Wang and L. Chu, "Irradiation treatment of pharmaceutical and personal care products (PPCPs) in water and wastewater: An overview," *Radiation Physics and Chemistry*, vol. 125. pp. 56–64, 2016.