ज्ञान–विज्ञान विमुक्तये

FINAL REPORT

Microwave-assisted rapid catalytic degradation of some Textile dyes using Poly(1-Napthylamine)

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Under
MAJOR RESEARCH PROJECT

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4. **ACHIEVEMENTS OF THE PROJECT**

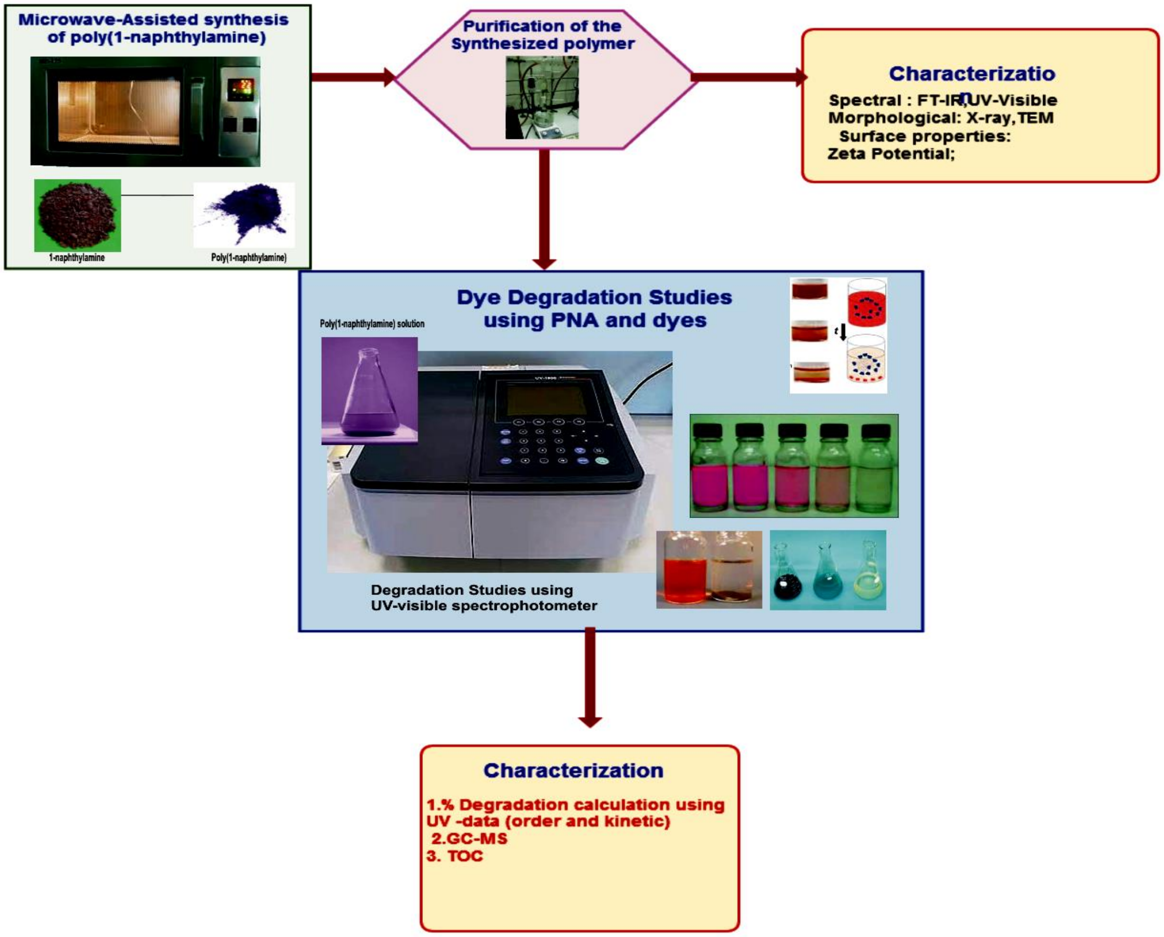
Appendix-I

PROJECT COMPLETION REPORT
(1st July 2012 - 31st August 2015)

1. OBJECTIVES OF THE PROPOSAL

The main objective of the present research work was to utilize poly(1-naphthyalmine) (PNA)- a conducting polymer as a catalyst for the microwave-assisted facile and rapid degradation of dyes such as *Orange G, Malachite green* in absence of any UV or visible light.

2. METHODOLOGY



3. WORK PLAN CARRIED OUT TO ACHIEVE THE OBJECTIVES

The following work has been done:

PHASE-I

1. Synthesis of poly(1-naphthylamine) (PNA) via microwave-assisted and emulsion techniques
    - 1.1. Spectral analysis of PNA: FTIR and UV-visible
    - 1.2. Morphological Analysis of PNA : XRD and TEM
    - 1.3. Determination of surface area and zeta potential

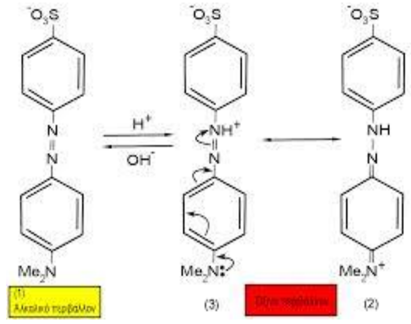
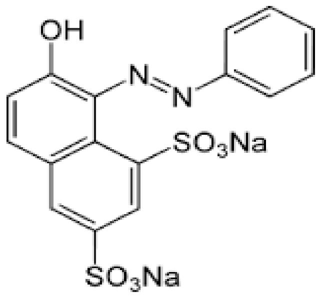
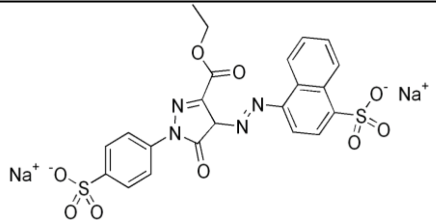
PHASE-II

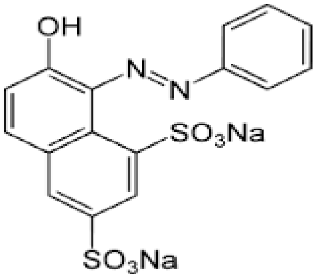
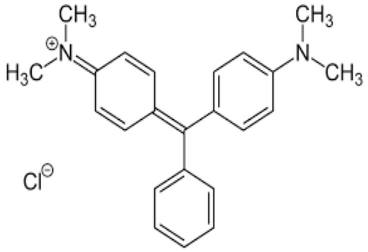
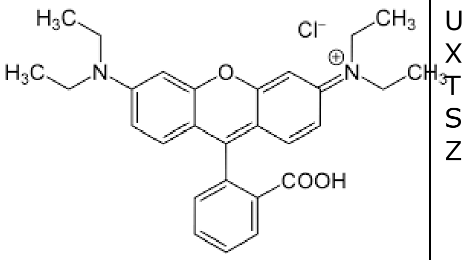
2. Degradation of dyes using PNA as catalyst via microwave-assisted technique and investigated
    - 2.1 Order and kinetics of degradation
    - 2.2 Effect of exposure time
    - 2.2 Effect of PNA loading on the degradation rate
    - 2.3 Effect of dye concentration (in ppm) on the degradation rate

PHASE-III

3. Monitoring the degradation of dye solutions using
    - 3.1 UV-visible
    - 3.2 TOC Analysis
    - 3.3 GC-MS Analysis

Apart form PNA, polyaniline, PNA nanocomposites and poly(o-toluidine) nanocomposites were also developed and investigated as catalysts for the degradation of various dyes as shown in the Table 1:

S.NO	CATALYST	DYE	CHARACTERIZATION OF THE CATALYST	TECHNIQUES USED FOR MONITORING DYE DEGRADATION
1.	PNA	**Methyl Orange**  	FT-IR UV-visible X-Ray TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC
2.	PNA (enzymatic)	**Orange G**  	FT-IR UV-visible X-Ray TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC
3.	Polyaniline (PANI)	 	FT-IR UV-visible X-Ray TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC

4.	PNA/ Bentonite nanocomposites	**Orange G** 	FT-IR UV-visible X-Ray TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC
5.	Poly(o-toluidine)/ Bentonite Nanocomposites	**Malachite Green** 	FT-IR UV-visible TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC
6.	Poly(o-toluidine)- NSA/ Bentonite Nanocomposites	**Rhodamine B** 	FT-IR UV-visible X-Ray TEM Surface Charge Zeta Potential	UV-visible GC-MS TOC

4. ACHIEVEMENTS OF THE PROJECT

4.1 Salient features of microwave-assisted degradation of methyl orange using poly(1-naphthylamine) as a microwave catalyst

Degradation of methyl orange (MeO) was investigated in neutral, acidic, and basic media under microwave irradiation using semiconducting polymer [poly(1-naphthylamine) (PNA)] nanotubes as catalyst in the absence of any light source. Degradation of the dye was followed spectrophotometrically and by total organic content (TOC) analysis.

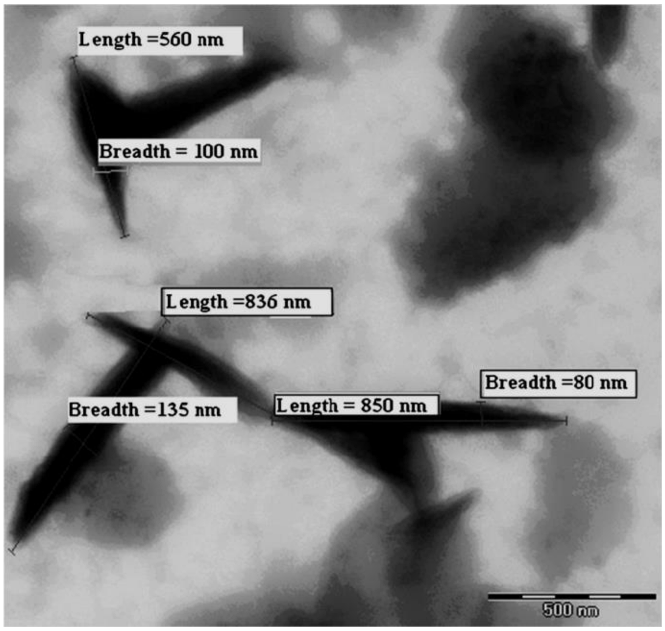


Fig.4.1 TEM of PNA

The TEM of PNA revealed tubular morphology of varying length formed through the reorganization of fluffy mass. The length was found to vary between 560 and 800 nm, while the breadth was observed to be ranging between 80 and 130 nm

Table 4.1 Degradation of Blank MeO solution and MeO-PNA solution of 150 ppm under microwave irradiation for 15 minutes in media of different pH

Dye solution	Wavelength (nm)	C/Co	*Degradation (%)	Correlation factor (R^2)	Rate constant (k)
Without catalyst					
MeO-150 (Neutral pH)	**280**	**0.75**	**25**	**0.9990**	**0.020**
	460	**0.65**	**35**	**0.9980**	**0.030**
MeO-150 (Acidic pH =3.0)	**280**	**0.80**	**20**	**0.9990**	**0.018**
	460	**0.73**	**37**	**0.9980**	**0.028**
MeO-150 (Basic pH =10.0)	**280**	**0.70**	**30**	**0.9980**	**0.020**
	460	**0.77**	**23**	**0.9980**	**0.030**
With PNA					
MeO-PNA-150 (pH=6.5)	**280**	**0.30**	**70**	**0.9990**	**0.060**
	460	**0.20**	**80**	**0.9990**	**0.120**
MeO-PNA-150 (pH =3.5)	**280**	**0.16**	**84**	**0.9980**	**0.073**
	460	**0.04**	**96**	**0.9980**	**0.150**
MeO-PNA-150 (pH =10.0)	**280**	**0.36**	**64**	**0.9980**	**0.130**
	460	**0.22**	**78**	**0.9980**	**0.200**

***** $\%Degradation = 1 - \frac{C}{C_o} x100$

The effect of pH on degradation of MeO in the presence of PNA was noticeable at both 280 and 460 nm. Over 10 % of difference in the degradation in the three pH regions matches with the two structures of MeO and their relative abundance. In the basic region, this difference is even more noticeable. In this region, the structure of MeO is different from that in the acidic region because of acid-base equilibria. This brings about change in its degree of degradation. PNA, a semiconducting polymer, is thus found to enhance the rate of degradation and acts as a polymeric catalyst. Its structure does not seem to permit any chemical involvement in degradation of MO as the NH protons are tightly bound. This leads to the involvement of water molecules in the degradation which are adsorbed on its surface.

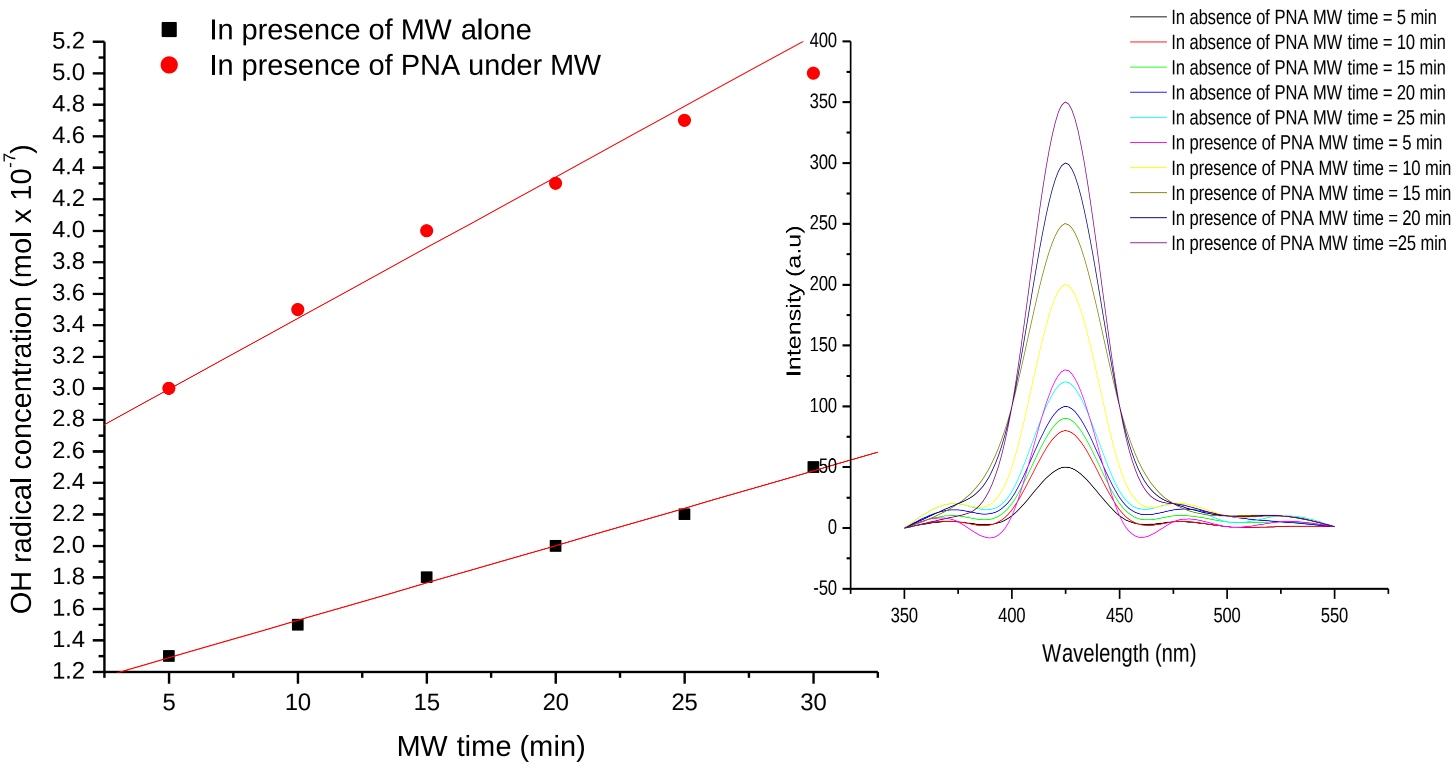
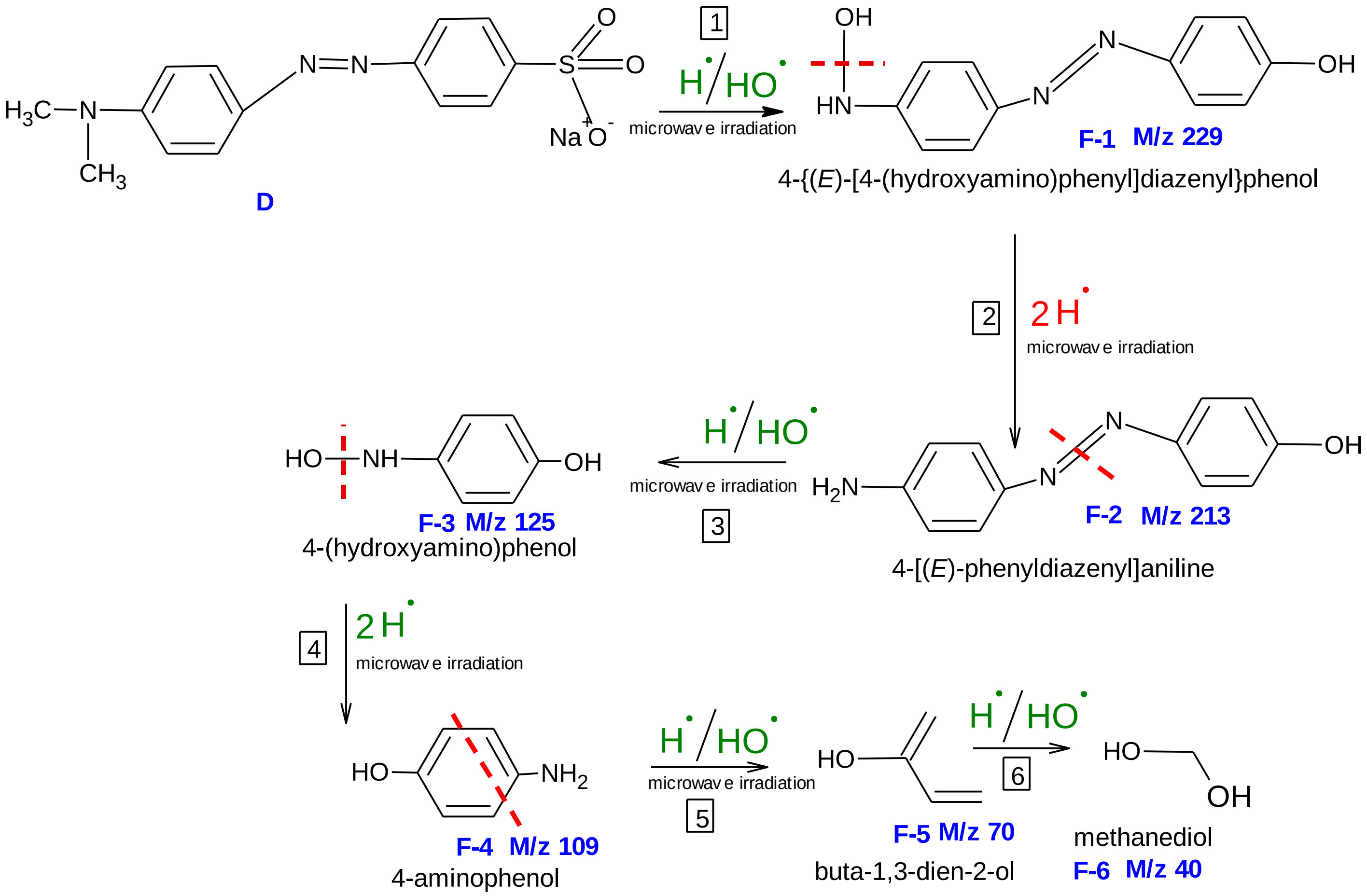


Fig.4.1.1 Formation of $OH^{\bullet}$ radicals in aqueous TA solution as a function of microwave irradiation time in the presence and absence of PNA

Using the fluorescence intensity integrated over the wavelength and the calibration curve for known concentrations of $OH^{\bullet}$ radicals (in the presence of 10^{-4} M of TA and 3×10^{-4} M of NaOH), we calculated the OH radical density in dye solution as a function of microwave irradiation time as shown in Fig. 4.1.1. The concentration of $OH^{\bullet}$ radicals increased linearly with increasing time. The concentration of $OH^{\bullet}$ radicals produced was observed to be higher in the presence of PNA than in its absence. This is because, in the dye solution, water molecules are preferentially adsorbed on the surface of PNA which also holds the sulphonate group of the dye molecules. Water molecules are also adsorbed and anchored on sulphonate group and dimethyl amino group of the dye.



Scheme 4.1 Identification of intermediates

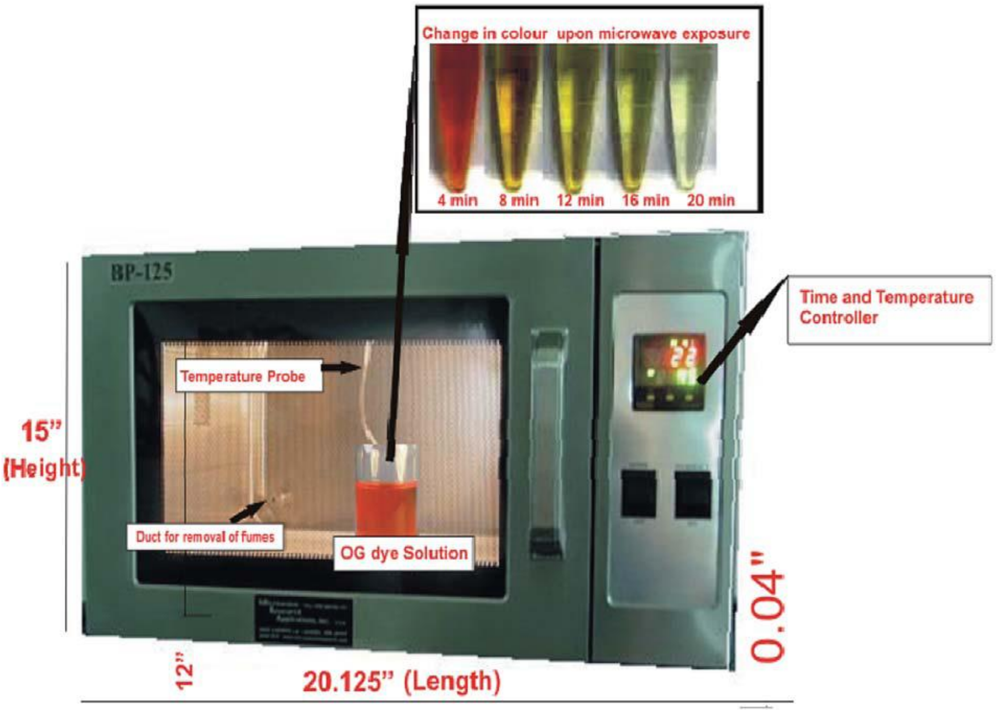
The fragments of the degraded dye at 20-min retention time are shown in Scheme 1. The dye was taken as the parent dye designated as D in Scheme 1, while intermediates with decreasing molar masses, m/z, 229, 213, 125, 109, 70, and 40 were taken as the daughter intermediates. The above intermediates are labeled as F-1, F-2, F-3, F-4, F-5, and F-6 (Scheme 4.1). microwave irradiation degraded the dye into intermediates with low molar masses, ultimately leading to mineralization only in the presence of PNA

Conclusion

Microwave irradiation was found to decolorize MeO dye in solution even in the absence of UV–visible radiation under neutral, acidic, and basic conditions in the presence of PNA as catalyst. MeO-150 revealed 35 % degradation in neutral media, while MeO-PNA-150 dye solution revealed 80, 96, and 78 % degradation in neutral, acidic, and basic media. PNA thus enhanced the degradation of the dye substantially. LC– MS technique recognized all intermediates formed during the degradation of methyl orange dye in the presence and absence of PNA and gave their molar masses, m/z values. The methodology adopted in this study demonstrates the efficiency of microwave irradiation for remediation of wastewater effluent from textile industries. PNA was found to be active until four cycles.

4.2 *Salient features of microwave-assisted degradation of Orange G using using poly(1-naphthylamine) as a microwave catalyst*

An attempt was made for the first time to degrade and mineralize Orange G (OG) dye in a laboratory microwave oven at 30°C, using an organic catalyst, poly(1-naphthylamine) (PNA), a conjugated polymer synthesized by an enzymatic method. PNA was characterized by relevant experimental techniques. The degradation was carried out by exposing the OG dye solutions to microwave irradiation for different time intervals in the absence of UV-vis radiation and TiO_2. PNA as a catalyst was found to enhance the dye degradation under microwave irradiation by almost two times as compared to its degradation under microwave irradiation alone.



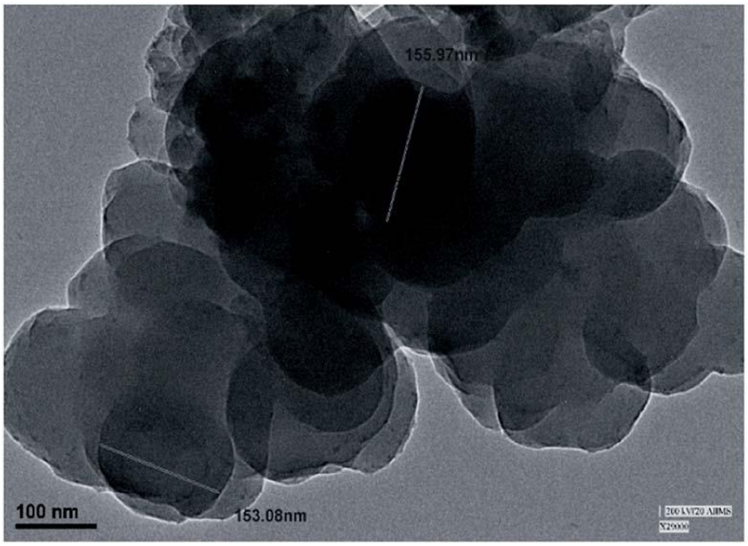


Fig.4.2 TEM of Enzymatically synthesized PNA

The spherical shape and the narrow size distribution of the particles, with an average diameter of 150–200 nm, was observed when CSA was used as doping agent for PNA, Fig.4.2 . The micrograph clearly shows formation of large aggregates which are expected to cause reduction in surface area of the PNA particle. The surface area was found to be 88 m^2/g and the average particle size around 150 nm. The PNA particles showed higher zeta potential value equal to 45 mV due to their colloidal nature

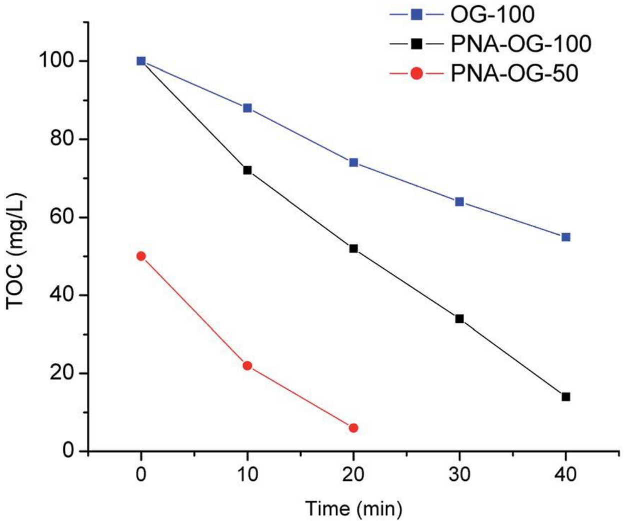


Fig.4.2.1 TOC analysis of PNA-OG-50 and PNA-OG-100.

Dye solutions, PNA-OG-100 and PNA-OG-50, showed a decrease in the TOC value with time of irradiation, Fig. 4.2.1. PNA-OG-100 mineralized to 84% by 40 min of microwave irradiation, while PNA-OG-50 mineralized to 86% by 20 min irradiation. Although, the pure dye solution reveals decolourization/degradation under microwave irradiation, from the beginning of the experiment, further degradation of some of the intermediates into smaller moieties were retarded due to factors related to energetics of the chemical reaction. However, PNA provides the surface for the adsorption of these intermediates and OH free radicals, and lowers the interaction energies causing further degradation of the intermediates resulting into mineralization. It is expected that microwave exposure of one hour or beyond will mineralize the dye solution to negligible TOC value

LC-MS analysis of the dye solution in presence of PNA revealed the intermediates at various retention times. In presence of PNA, PNA-OG-100 dye solution degraded into intermediates of m/z: 227, 222, 210, and 113. The intermediate m/z: 113 was the main product at retention times 5.30 min, 11.74 min and 12.25 min, and intermediate m/z: 210 at retention times 4.0 min and 4.31 min. It is therefore clear that parent dye degrades fast into intermediates of smaller molar mass. Intermediates with molar mass less than m/z 113, like m/z 97, 62, and 59.9, were also encountered,Fig.4.2.2. This showed that degradation in presence of PNA was fast and continued to form intermediates of smaller molar masses which were not recorded by the MS system.

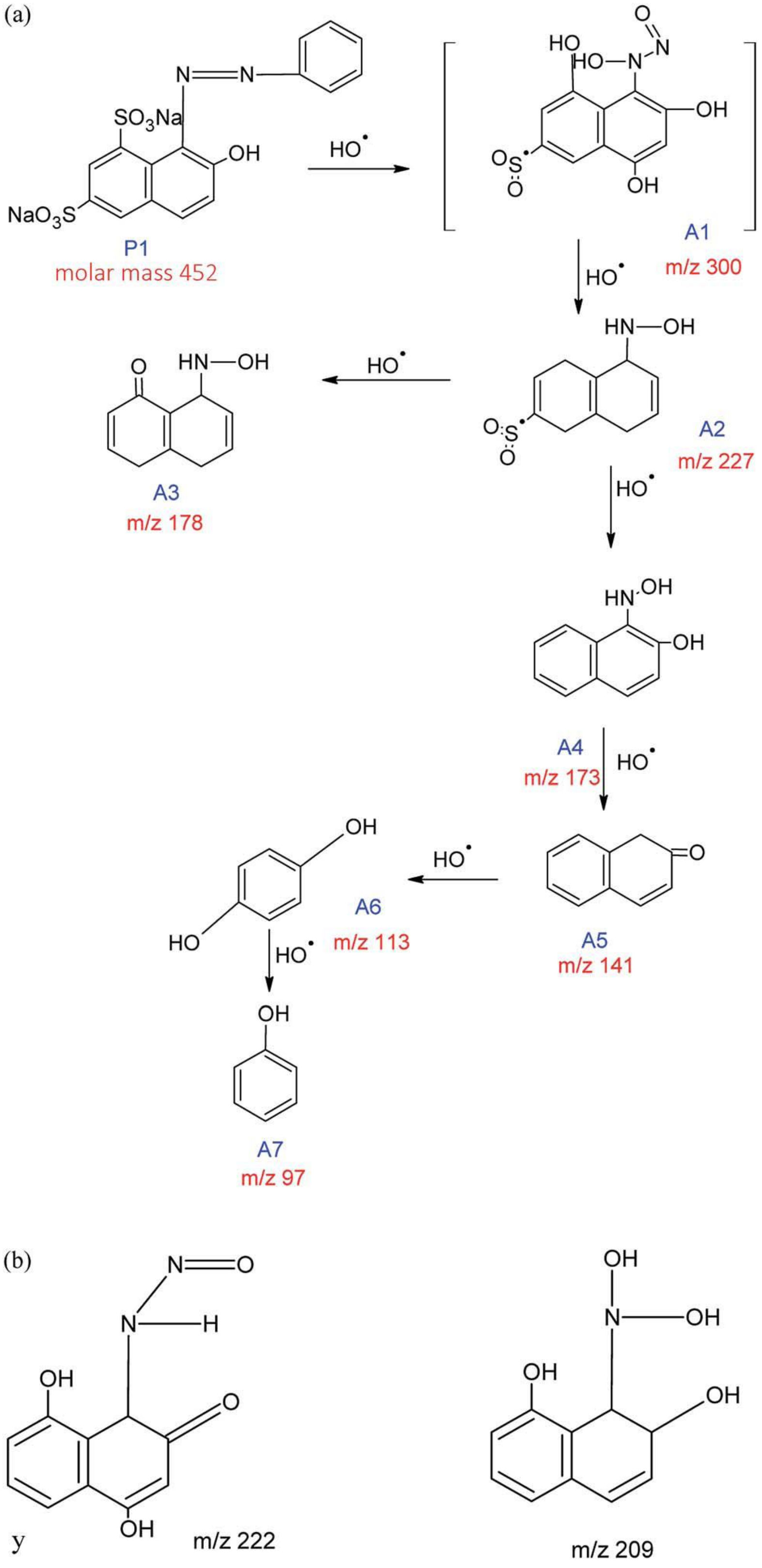


Fig. 4.2.2 (a) Identification of intermediates. (b) Identification of alternate intermediates

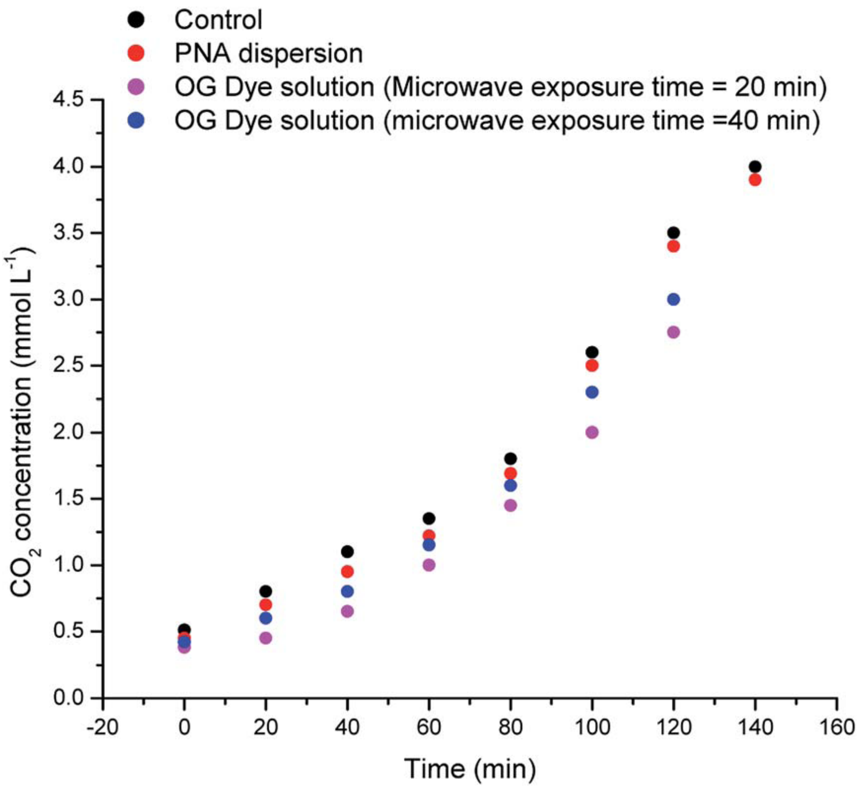


Fig.4.2.3 CO_2 evolution in control and test solutions at different incubation times.

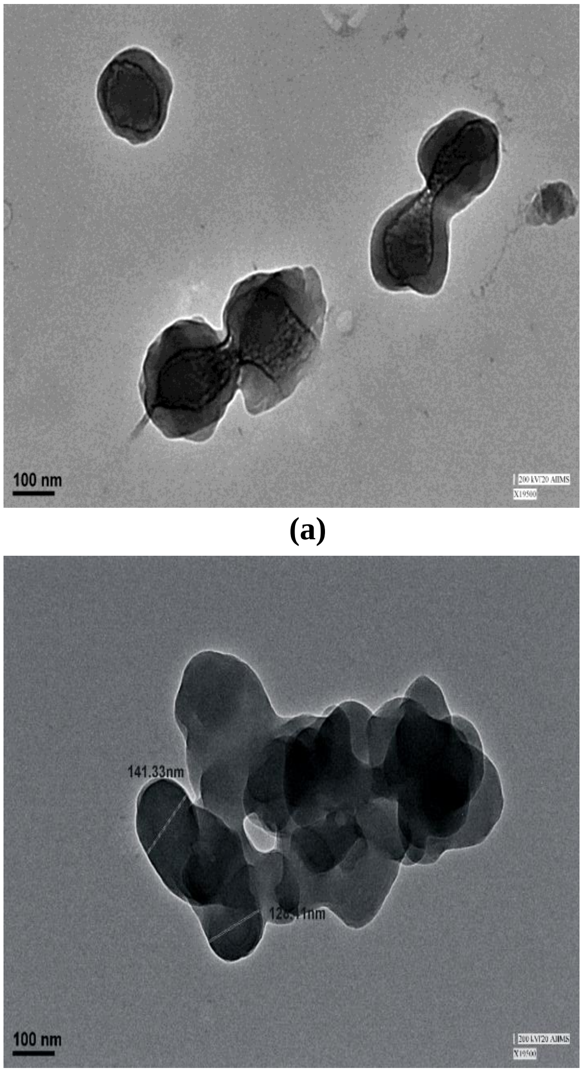
Toxicity studies revealed that for 20 min and 40 min microwave irradiation, acute toxicity (% inhibition) of OGPNA dye solution was 25% and 16%. The PNA dispersion showed CO_2 evolution matching with the control. As was observed earlier if microwave exposure is further enhanced, the acute toxicity level is expected to further go down

Conclusion

Microwave irradiation was found to decolorize OG dye solution even in absence of UV-visible radiation and inorganic photocatalyst in the microwave oven used at 30°C. PNA, was found to enhance the rate of degradation. In presence of PNA, 100 mL of 100 ppm dye solution degraded to 90% in 20 min, while the same solution of dye in absence of PNA degraded only to 45% in the same time.

4.3 *Salient features of microwave-assisted degradation of Orange G using using poly(1-naphthylamine)/Bentonite as a microwave catalyst*

A nanohybrid of poly(1-naphthylamine) (PNA) with bentonite was synthesized for its application as an efficient catalyst for the rapid degradation of Orange G via microwave irradiation. Fourier transform infrared spectroscopy (FT-IR) revealed emeraldine form of PNA in the nanohybrid while ultraviolet-visible (UV-Vis) spectra established the conducting state of Bent/PNA nanohybrid. Formation of vertical chains of PNA in the interlayer space of bentonite clay was established by XRD. TEM showed core–shell structure of the Bent/PNA nanohybrid with size in the range 140-200 nm Fig.4.3.



(a)

(b)

Fig.4.3 TEM of (a) Bent/PNA 1:0.25 (b)Bent/PNA 1:0.5

Table 4.3 Surface area and textural properties of Bentonite, PNA and Bent/PNA nanohybrids

Samples	Surface area (m^2 g^{-1})	Pore diameter (nm)
Bentonite	88	1.4
PNA	90	4.5
Bent/PNA 1:0.25	104	1.8
Bent/PNA 1:0.5	122	2.4
Bent/PNA 1:1	94	1.6

Table 4.3.1 Retention times of Bentonite and Bent/PNA nanohybrid

Sample	Retention time (min)	Intermediates with % abundance
Bentonite-OG-80	20	285 (100%), 103 (95%), 223 (72%), 141(70%)
Bent/PNA-G-80	11.7	119.03(100%), 113(50%), 227(20%)
	12.5	59 (100%), 119 (100%),
	13.3	119 (100%), 89 (35%), 104 (25%),
	18.7	59.03 (100%), 119 (10%)
	19.4	113 (100%), 120 (50%), 103 (45%), 59.9 (42%),

It can be seen from the Table 4.3 ,the surface area increase from 88 to 122 m^2 g^{-1} and pore diameter from 1.4 to 2.4 nm starting from neat bentonite to Bent/ PNA 1:0.5. This indicates that the textural properties (surface area and pore diameter) increases after intercalation of PNA. Beyond Bent/ PNA 1:0.5 the surface area and pore diameter decrease. This is because increase of PNA content causes the blocking of the pores and some agglomeration of particles.

LCMS results with Bent/PNA 1: 0.5 at retention times 11.7 min, 12.5 min, 13.3 min, 18.7 min, and 19.4 min reveal intermediates of different m/z values with different abundances, Fig.4.3.1. It was found that when dye solution alone or with bentonite was exposed to microwave radiation, the water split into H· and OH· free radicals through the action of nonthermal effect of microwave radiations. The nonthermal effect has been observed by other authors as well to enhance the degradation of the dye by enhancing the formation of OH· free radicals.

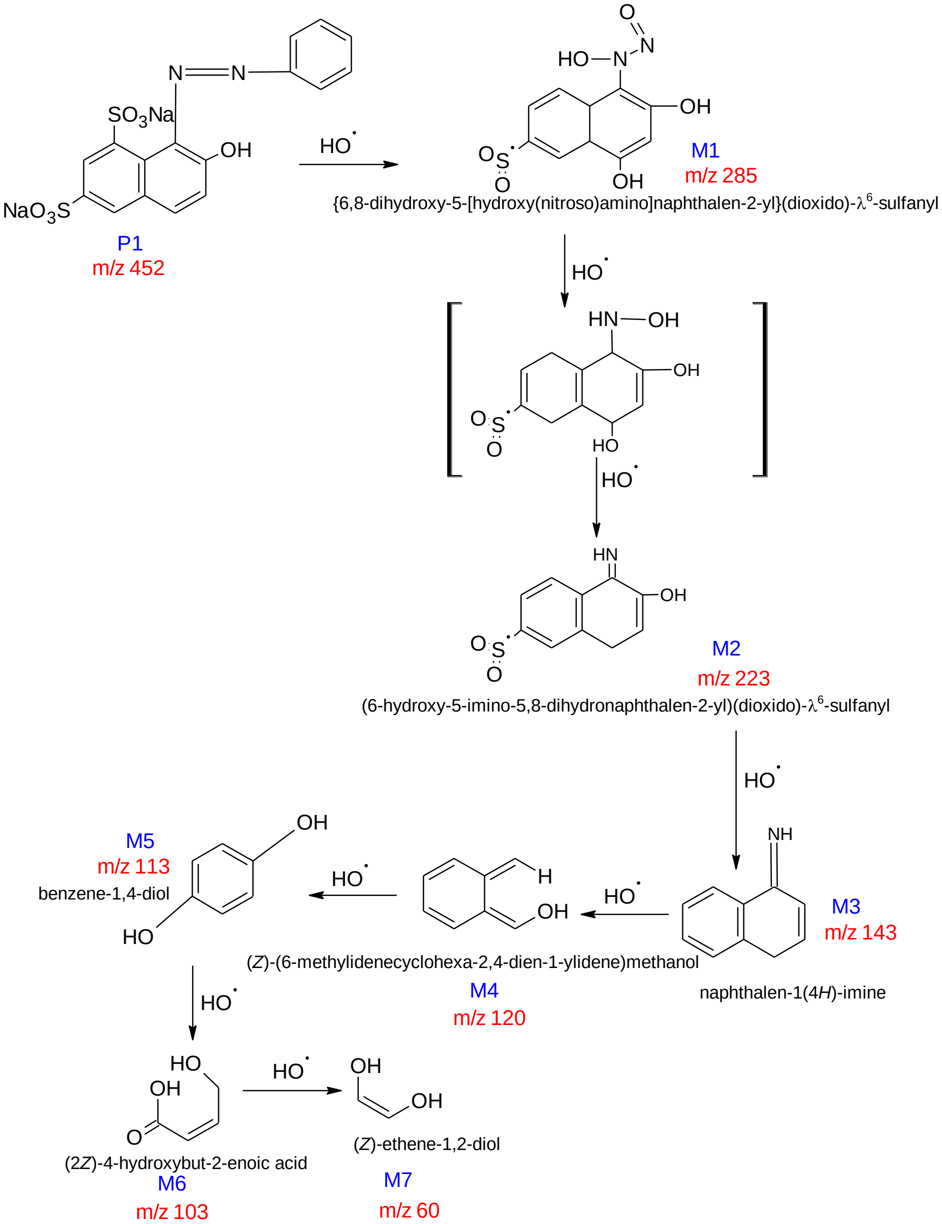


Fig.4.3.1 Tentative Degradation pathway of OG in presence of Bent/PNA nanohybrid

Conclusion

Microwave radiation provides an easy and fast method for solid-state polymerization and intercalation of PNA in the interlayer space of Bentonite. Inside the clay gallery the PNA chains were coiled and were oriented vertically. Bent/PNA nanohybrid was found more electroactive than pristine PNA. It showed good catalytic activity in the degradation of Orange G dye under microwave irradiation at 30^0C. The degradation of the dye followed first order rate kinetics. LC-MS results showed that PNA/ Bent nanohybrid rapidly catalyzed the degradation of orange G dye into intermediates of fairly low m/z values 119, 113 and 60. Nanohybrid catalyst was found to be active up to 6 cycles.

4.4 *Salient features of microwave-assisted degradation of Acid Orange using using poly(aniline) as a microwave catalyst*

Degradation of acid orange 7 (AO) under microwave irradiation was carried out using polyaniline (PANI) as catalyst in the absence of any UV lamp as light source. The degradation/decolourization was carried out in neutral acidic and basic media and was monitored spectrophotometrically to evaluate the ability of microwave irradiation to degrade AO. Microwave irradiation showed excellent performance as it completely decolourizes AO dye solution in 10 min.

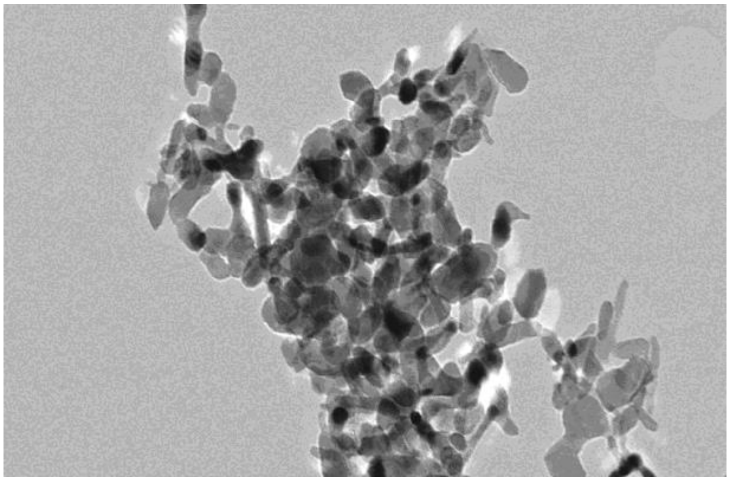


Fig.4.4 TEM of PANI

The TEM micrograph of PANI, Fig.4.4, revealed large clusters of elongated PANI nanoparticles of size 35–40 nm. The particles were longitudinally shaped forming a dense self-assembled nanostructure.The resulting particle appeared to be interconnected and nearly of the same size. TEM thus confirmed the nanosize of PANI synthesized by the template method.

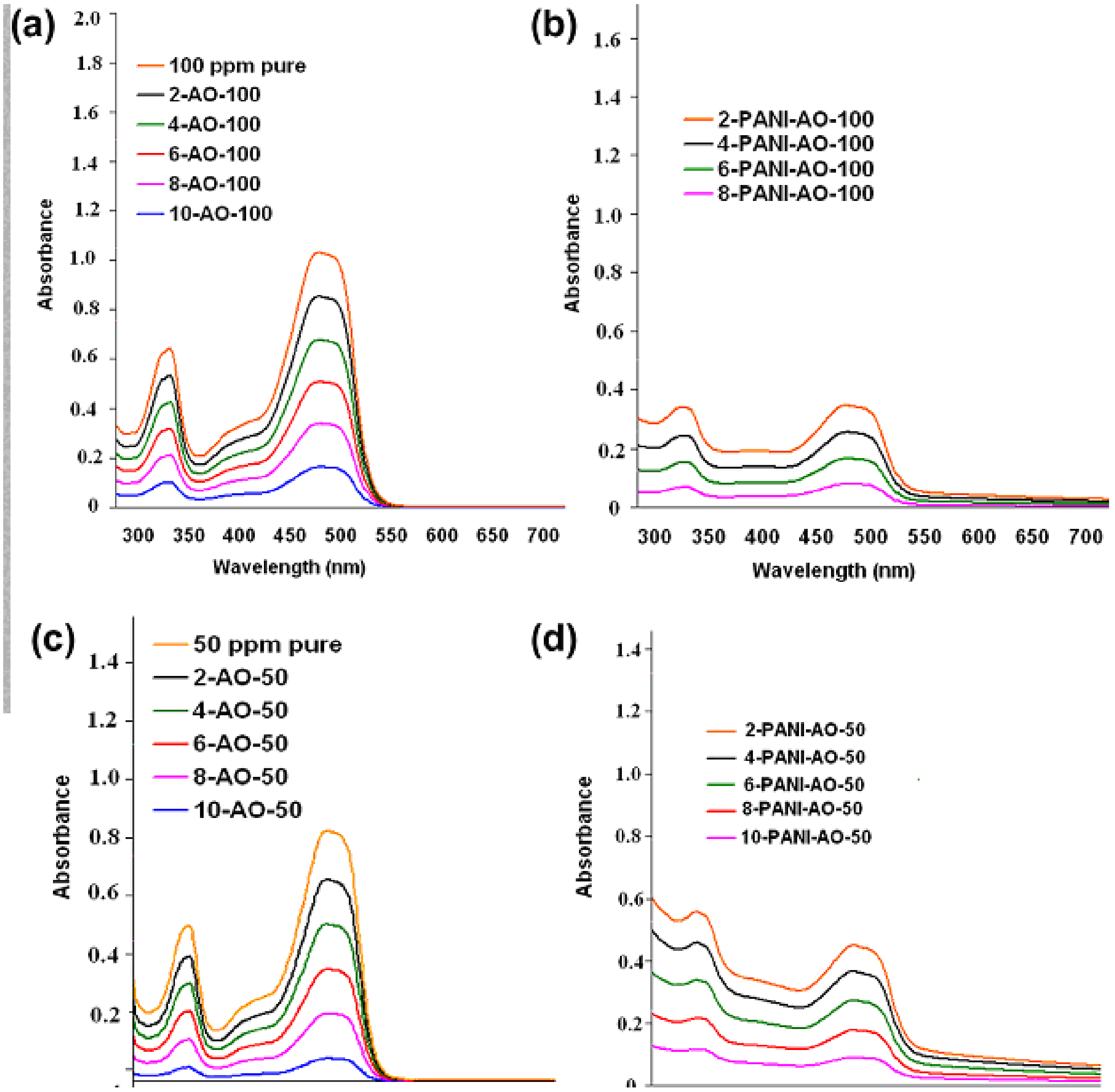


Fig.4.4.1 UV–Visible spectra of AO-100 and AO-50 in neutral medium exposed to microwave radiation (a) AO-100 (b) PANI-AO-100, (c) AO-50 and (d) PANI-AO-50.

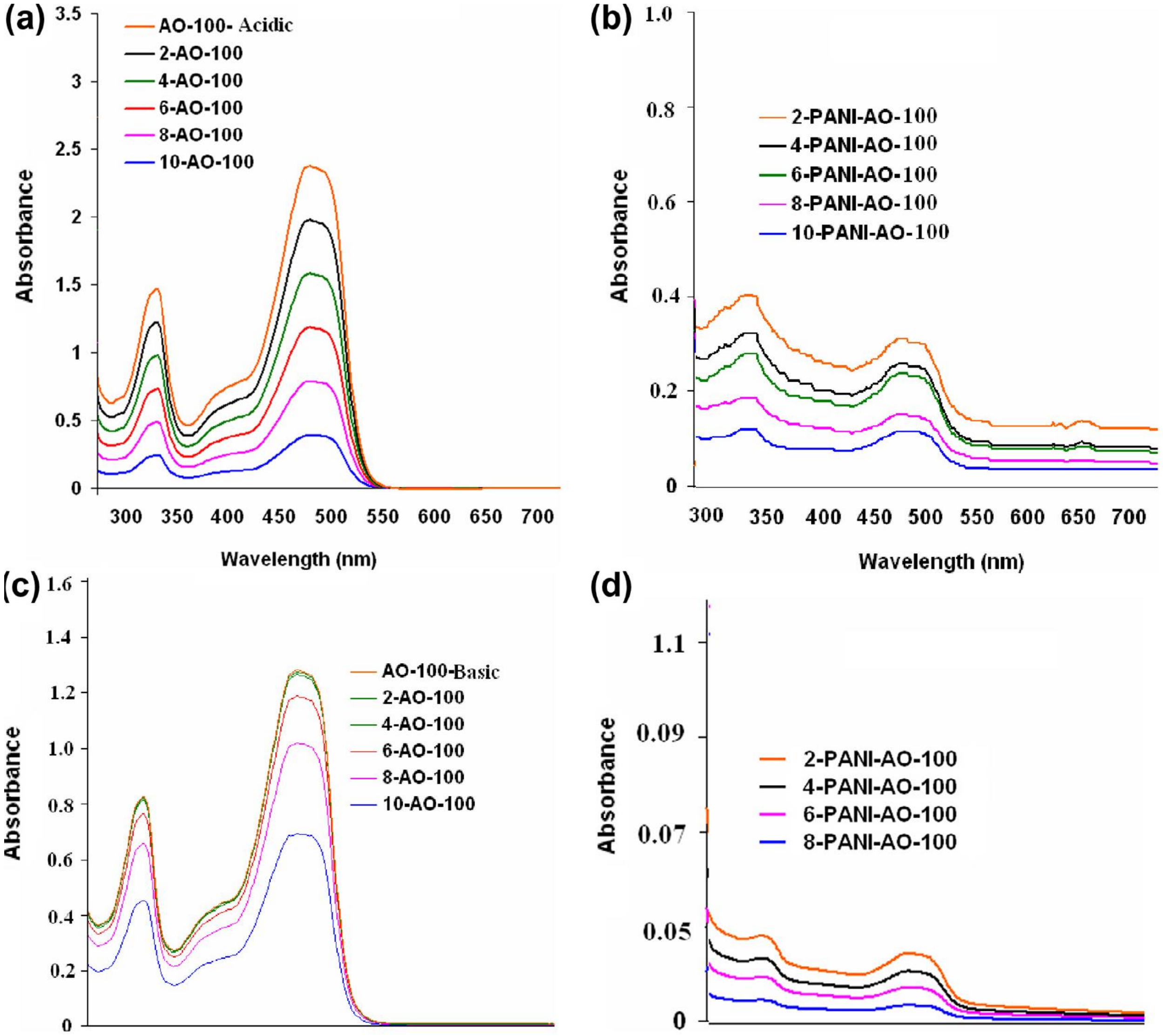


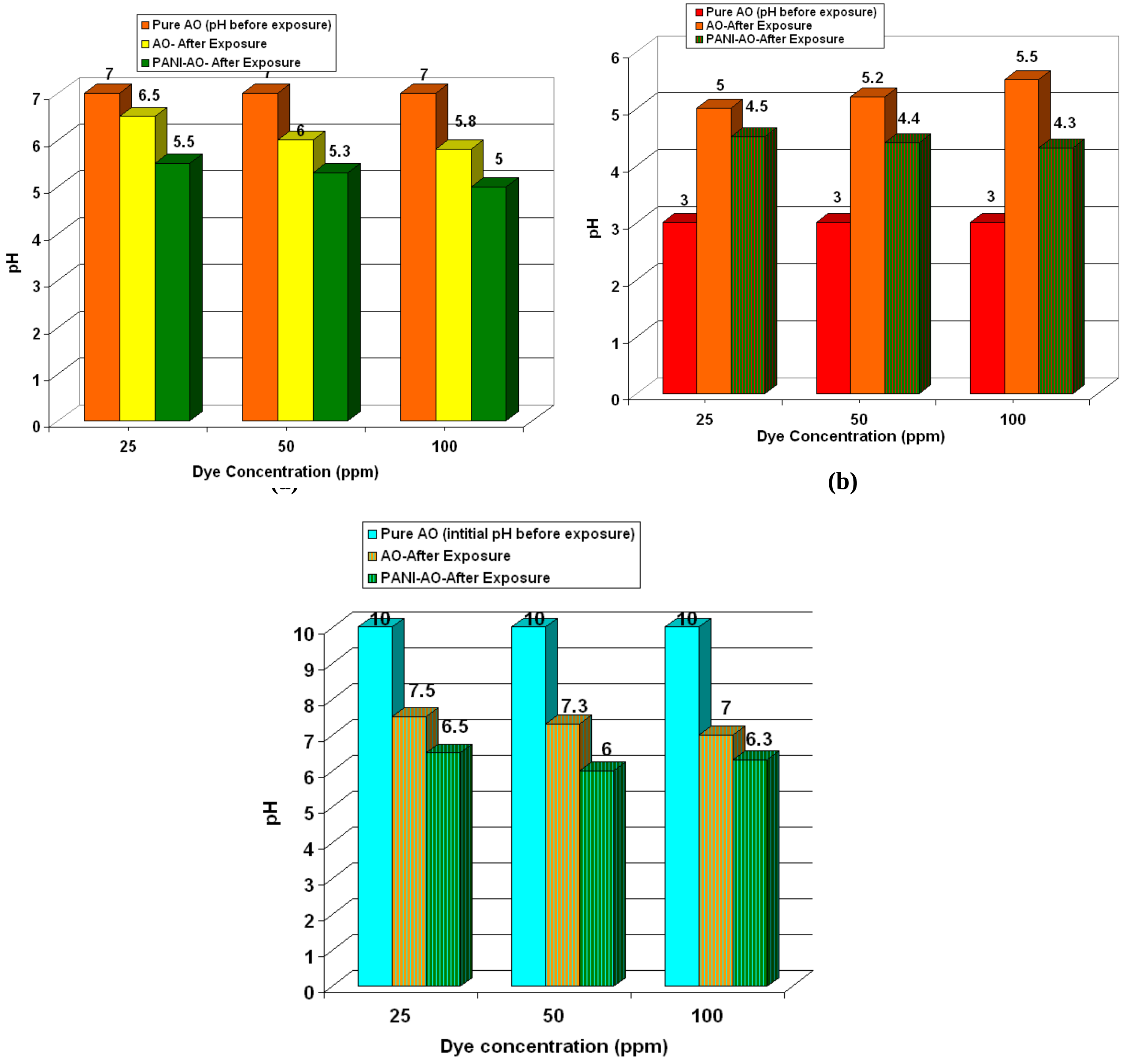
Fig.4.4.2 UV–Visible spectra of (a) AO-100 (in acidic medium) (b) PANI-AO-100 (in acidic medium) (c) AO-100 (in basic medium) (d) PANI-AO-100 (in basic medium).

The decrease in the absorbance intensity of the 480 nm was caused by the chemical modification of the azo group. The decrease in the absorbance intensity of the peak at 330 nm resulted from elimination of the azo group and modification of the naphthalene ring. It was observed that the absorbance intensity at both k= 480 nm and k= 330 nm decreases with time which respectively showed the decolourization and degradation of the dye with time.The decrease in the absorbance intensity of the peaks in the UV and visible regions was higher as in acid medium as compared to the neutral medium which confirmed rapid degradation of the AO dye in acidic medium.

The pH of the AO dye solutions, Fig.4.4.3 (a–c), before and after exposure was monitored to study the change in pH upon microwave irradiation. In case of neutral medium, the AOdye solutions showed a decrease in the pH after exposure, while PANI-AO exposed solutions revealed much lower pH as compared to AO dye solutions. Likewise, in case of the AO acidic dye solutions, the pH was found to increase from 3 to around 5 for AO-dye solutions and to 5.5 for PANI-AO dye solutions. The pH of basic solutions exposed to microwave irradiation was found to be around 7.3 for AO-dye solutions and 6.5 for AO-PANI dye solutions. The change in the pH was attributed to the generation of H^+ and OH^- ions consequent to the generation of OH^- and H^+ free radicals by nonthermal effects of microwave irradiation. These ions lead to the increase in the pH incase of acidic solutions and decrease in the pH incase of neutral and basic solutions. Formation of intermediates during degradation of the dye also contributed in the increase and decrease of the pH.

Conclusion

Microwave irradiation shows remarkable decolorization/degradation of AO7 dye. Complete decolorization/degradation of 100 mg/L dye solution was achieved in 10 min. 65% of OG-PANI-100 dye solution mineralized in 40 min under microwave irradiation. The degradation and mineralization of AO7 at 30°C in the presence of PANI by microwave irradiation showed better performance than other reported methods. A large mount of OH free radicals were generated in AO dye solution under microwave irradiation to degrade AO7 dyes effectively.



(a)

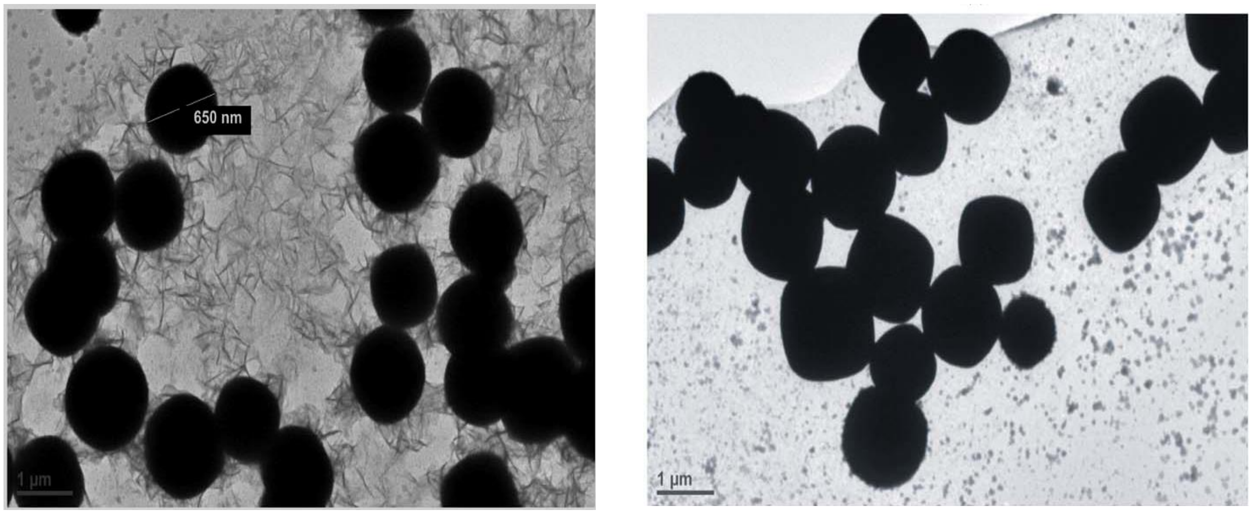
(b)

(c)

Fig.4.4.3 Change in pH upon exposure to microwave irradiation

4.5 *Salient features of microwave-assisted degradation of Malachite Green using using poly(o-toluidine)/Bentonite as a microwave catalyst*

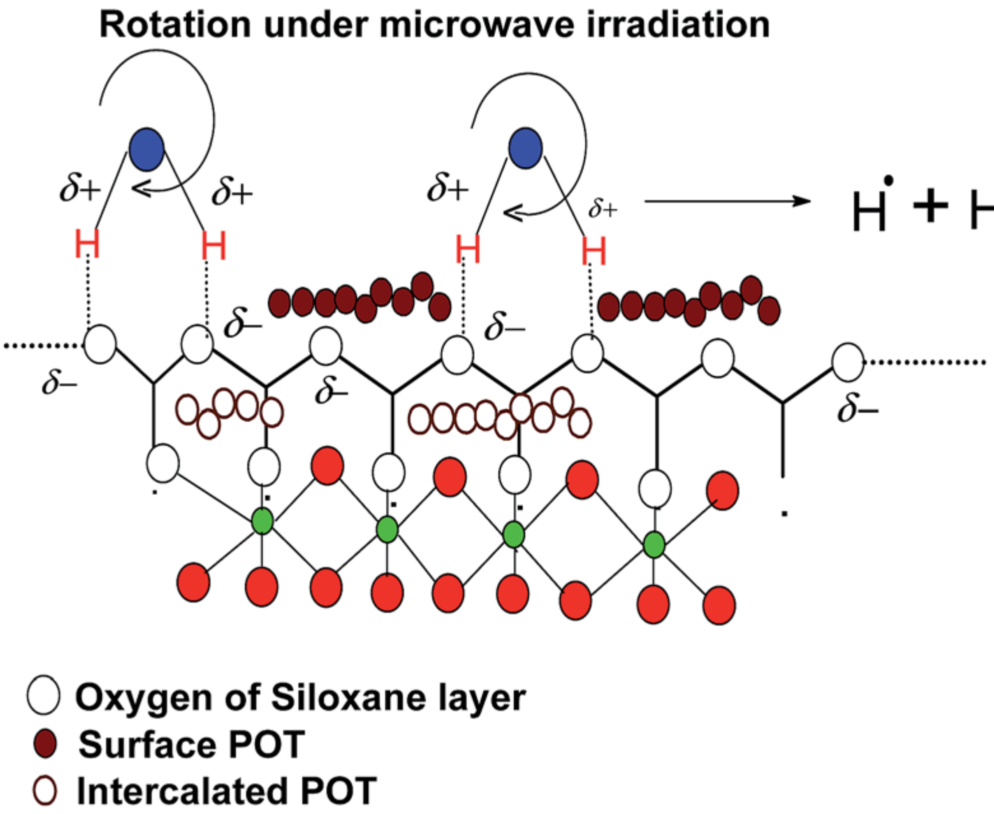
The potential use of natural clay based organic–inorganic hybrids as ecofriendly catalyst was investigated for the degradation of Malachite Green under microwave irradiation. Bentonite–poly(o-toluidine) nano hybrid was prepared through microwave-assisted solid state in situ intercalation and polymerization. The intercalation of poly(o-toluidine) was confirmed by X-ray diffraction analysis, while its conducting state was confirmed by UV-visible spectroscopy. Transmission electron microscopic studies revealed that poly(o-toluidine) extracted from the bentonite interlayer space formed nano spheres and tablets of controlled dimensions. The catalytic efficiency of the nanohybrid in degrading Malachite Green under microwave irradiation was investigated in 100 ppm dye solution in the presence of 200 mg of the catalyst for different time intervals.



(a) **(b)**

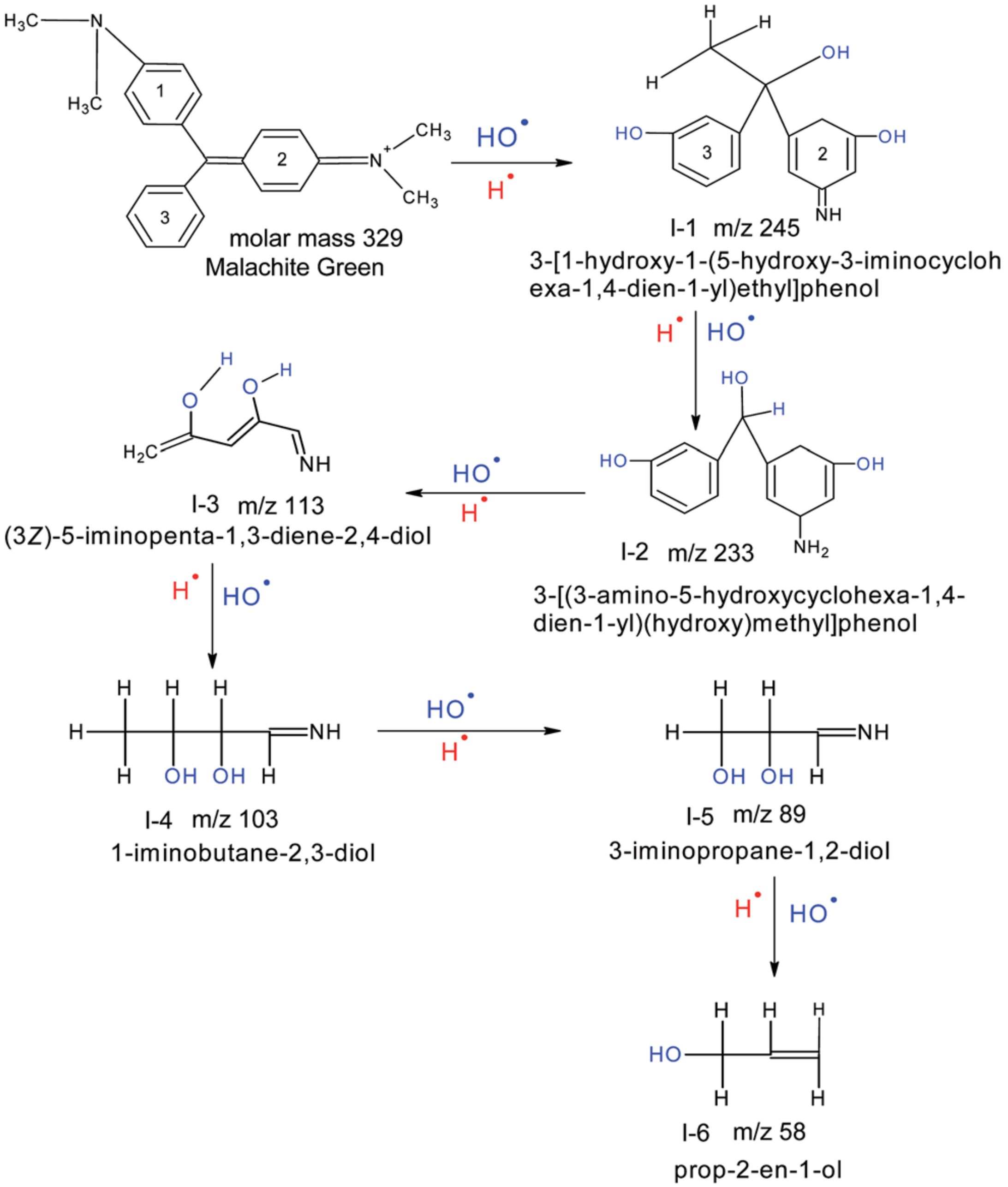
Fig.4.5 TEM micrographs of (a) bentonite : POT 1 : 0.5-30 °C (POT extracted from bentonite), (b) bentonite : POT 1 : 0.5-40 °C (POT extracted from bentonite).

The particles appear to be nearly of the same size and morphology which confirms the controlled growth of POT outside bentonite galleries. It appears that spheres and tablets are formed by the self-assembly of fibers of POT particles. Self-assembly of POT inside the bentonite galleries takes place through the coiling of POT chains. The hydrophobic interactions between the OT units of POT chains impart stability to the small spherical and fiber like structure of POT particles



Scheme.4.5 Orientation of the water moleules in presence of microwave

The water molecules are copiously adsorbed on negatively charged site of the nanohybrid surface, Scheme 4.5 . Under microwave irradiation, the water molecules are subjected to orientation polarization but electrostatic attraction between the two oppositely charged polar groups (Scheme 4.5) does not permit the water molecules to flip. This produces enormous strain in OH bonds of water molecules. Since the two hydrogens are not pulled by equal force by the negatively charged oxygen of the nanohybrid, charge density not being equal at all the negative sites because of perturbation; water molecules will split into Hc and OHc free radicals. Other undefined non thermal effect may also have contributed to the splitting of water molecules into OH and H free radicals.



Scheme 4.5.2 Degradation pathway of MG in presence of nanohybrid

Catalytic degradation of MG dye was further confirmed through analyzing the partially degraded samples of the dye by LC-MS method. The catalyst degraded the dye into much smaller fragments as compared with degradation products in its absence in the same time. Since the degradation products was mainly linear chain unsaturated alkanes and alcohols which are found to be toxic, TOC analysis at different times of degradation has been done to find out the extent of mineralization and remaining organic content, and its was found that after 20 min of degradation, the organic content left in the dye solution was only 6%. This indicates nanohybrid catalyst almost mineralizes the dye and toxic products left are negligible. Hence this nanohybrid can be adopted for the safe degradation of toxic dyes

Conclusion

Organic–inorganic nanohybrid catalyst, bentonite–poly(o-toluidine), was developed to replace extensively used nanosized but potentially toxic TiO_2, ZnO and other inorganic semiconductor photocatalysts. This nanohybrid catalyst stands as a potential candidate for environmental remediation under microwave irradiation even in absence of UV-visible light. LC-MS analysis showed degradation of Malachite Green into intermediates of so low a molar mass as m/z 89 and 58 which mineralized into CO_2 and water upto 94%. Thermal degradation of the dye was confirmed to occur through hydroxyl and hydrogen free radicals generated under microwave irradiation by splitting of H_2O molecules. This nanohybrid catalyst stands as a potential candidate for environmental remediation under microwave irradiation even in absence of UV-visible light.

6. SUMMARY OF THE FINDINGS

PNA holds immense potential as a microwave catalyst and its performance is comparable to that of the photocatalysts that are being currently used. We have developed a microwave-active catalyst that works as efficiently as commonly used photocatalysts in absence of any UV-visible radiation and within a short span of time. The degradation rate and mechanism were found to vary with the type of catalyst used i.e nanocomposite or any other conducting polymer such as poly(o-toluidine),poly(aniline).The degradation by-products produced were non-toxic as compared to those produced using photocatalysts. The effect of exposure time did not significantly effect the percent degradation incase of all the dyes. Also higher loading of PNA did not influence the degradation rate.

- Microwave irradiation was found to decolorize methyl Orange (MeO) dye in solution even in the absence of UV–visible radiation under neutral, acidic, and basic conditions in the presence of PNA as catalyst. MeO-150 revealed 35 % degradation in neutral media, while MeO-PNA-150 dye solution revealed 80, 96, and 78 % degradation in neutral, acidic, and basic media. PNA was found to be active until four cycles.
- Microwave irradiation was found to decolorize OG dye solution even in absence of UV-visible radiation and inorganic photocatalyst in the microwave oven used at 30°C. PNA, was found to enhance the rate of degradation. In presence of PNA, 100 mL of 100 ppm dye solution degraded to 90% in 20 min, while the same solution of dye in absence of PNA degraded only to 45% in the same time.
- Bent/PNA nanohybrid was found more electroactive than pristine PNA.The degradation of the dye followed first order rate kinetics. LC-MS results showed that PNA/ Bent nanohybrid rapidly catalyzed the degradation of orange G dye into intermediates of fairly low m/z values 119, 113 and 60. Nanohybrid catalyst was found to be active up to 6 cycles.

- The degradation and mineralization of AO7 at 30°C in the presence of PANI by microwave irradiation showed better performance than other reported methods. A large mount of OH free radicals were generated in AO dye solution under microwave irradiation to degrade AO7 dyes effectively.
- Organic–inorganic nanohybrid catalyst, bentonite–poly(o-toluidine), was developed to replace extensively used nanosized but potentially toxic TiO_2, ZnO and other inorganic semiconductor photocatalysts. This nanohybrid catalyst stands as a potential candidate for environmental remediation under microwave irradiation even in absence of UV-visible light. LC-MS analysis showed degradation of Malachite Green into intermediates of so low a molar mass as m/z 89 and 58 which mineralized into CO_2 and water upto 94%. Thermal degradation of the dye was confirmed to occur through hydroxyl and hydrogen free radicals generated under microwave irradiation by splitting of H_2O molecules. This nanohybrid catalyst stands as a potential candidate for environmental remediation under microwave irradiation even in absence of UV-visible light.

7. CONTRIBUTION TO THE SOCIETY

Environmental remediation is a site specific action that depends on the environmental characteristics of a particular site, the type of contamination and available technologies. Hence, the costs for remediation also vary from site to site. Remediation actions need to be justified and optimized. The end result is always a balance between risks, costs, benefits and remediation viability. Organic semiconductor nanostructures can play an important role in as smart materials that can simultaneously sense and destroy harmful chemical contaminants from the environment. Such an application seems to be important as the concern over chemical contamination of drinking water and air needs to be addressed. Application of organic semiconductor nanoparticles as microwave catalysts is still in its infancy.

We have developed a fast efficient and a facile technique for the rapid degradation of dyes that holds immense potential for commercialization. This technology can be implicated in terms of

- environmentally friendly processes
- handful of opportunities for the production of renewable and clean energies
- Remediation of many toxic byproducts that are unfriendly or even more toxic as compared to parent dye.

8. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT

02 students have enrolled for PhD out of the project in 2013

- *Mrs.Anurakshi Verma (MPhil. Kanpur Univeristy)*
- *Miss Jyoti Kashyap (MPhil, Delhu University)*

9. NO. OF PUBLICATIONS OUT OF THE PROJECT

1. Ufana Riaz, S.M.Ashraf and Jyoti Kashyap, *Enhancement of Photocatalytic properties of transitional metal oxides using conducting polymers: A Mini Review*, Materials Research Bulletin, 2015, 71, 75-90.
2. Ufana Riaz, S.M.Ashraf and Anurakshee Verma, *Recent Advances in the Development of Conducting Polymer Intercalated Clay Nanocomposites: A Short Review*, Current Organic Chemistry, 2015*,* 19, 1275-1291.
3. Ufana Riaz, S.M.Ashraf and Ankur Ruhela, *Catalytic degradation of orange G under microwave irradiation with a novel nanohybrid catalyst*, Journal of Environmental Chemical Engineering, 2015,3-20-29.
4. Ufana Riaz and S.M.Ashraf, *Microwave-induced catalytic degradation of a textile dye using bentonite–poly(o-toluidine) nanohybrid*, RSC Adv., 2015,5, 3276–3285.
5. Ufana Riaz and S.M.Ashraf, *Synergistic effect of microwave irradiation and conjugated polymeric catalyst in the facile degradation of dyes*, RSC Adv., 2014,4,47153–47162.
6. Ufana Riaz, S.M.Ashrad and Munazah Farooq,*Effect of pH on the microwave-assisted degradation of methyl orange using poly(1-naphthylamine) nanotubes in the absence of UV–visible radiation*, Colloid and Polymer Science, 2015,
7. Ufana Riaz S.M.Ashraf and Mohd.Aqib *Microwave-assisted degradation of acid orange using a conjugated polymer, polyaniline, as catalyst.* Arabian Journal of Chemistry, (2014) 7, 79–86.
8. *Ufana Riaz, and S.M.Ashraf, Evaluation of Antibacterial Activity of Nanostructured Copolymers of Poly (Naphthylamine),* International Journal of Polymeric Materials, 2013,62,406–410.
9. *Ufana Riaz and S.M.Ashraf .Catalytic Activity of Poly(o-toluidine)/ Montmorillonite Nanocomposites towards Microwave-assisted Degradation of Rhodamine B,* Materials Research Bulletin (under Review)

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18/2/19

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Date 18/2/19

JMI Mail

Dr. Ufana Riaz (Assistant Professor, D/o Chemistry) <uriaz@jmi.ac.in>

UGC project completion report to be uploaded at JMI website (Dr.Ufana Riaz)

1 message

Dr. Ufana Riaz (Assistant Professor, D/o Chemistry) <uriaz@jmi.ac.in> Thu, Feb 14, 2019 at 1:12 PM
To: "Prof. S.M.K. Quadri (Hony Director, FTK-CIT)" <quadrismk@jmi.ac.in>, "Prof. Tanvir Ahmad (Hony. Addl. Director: Website & MIS)" <tahmad2@jmi.ac.in>
Cc: Azizullah Khan <aukhan@jmi.ac.in>

Dear Sir,

I had successfully completed my UGC Major research project entitled " Microwave-assisted Catalytic degradation of some textile dyes using poly(-1-naphthylamine) (2012-2015).
As per UGC guidelines and a recent reminder sent by the Under secretary, a copy of the completed project is to be uploaded at JMIs website.at the following URL: https://www.jmi.ac.in/bulletinboard/researchproject/latest

I am therefore sending the pdf file of the said project as attachment for your kind perusal.

Thanking you and with kind regards,
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