Universe Scientific Publishing

ORIGINAL ARTICLE

Application of the Microwave Technology to the Environmental Protection

Jianhong Wang[1*], Lianhe Yan[1], Shenfan Zhou[1] and Debao Liu[2]

[1] Water Treatment Institution, Nanjing University of Science & Technology, Nanjing, Jiangsu 210094, China

[2] Tangshan Iron and Steel Co., Ltd., Tangshan, Hebei 063020, China

ABSTRACT The microwave irradiation technologies applied to environmental protection is surveyed. The mechanism and features of microwave irradiation and the microwave technologies applied to wastewater are emphasized especially. Waste gas and waste solid treatment, environmental protection materials production and environmental monitor and the problems of the technologies are discussed the applicable prospect of the microwave technology in the environmental protection.

KEYWORDS
Microwave
Irradiation mechanism
Wastewater
Waste solid
Environmental monitor

1. Introduction

Since 1970 the use of microwave devices successfully processed nuclear waste since, microwave technology quickly spread to the chemical field. The past ten years have been noted in microwave potential field of environmental protection. Microwave heating mechanism and characteristics of wastewater, waste gas, solid waste treatment, research, environmental monitoring and other environmentally friendly materials have carried out extensive research on the development direction of our microwave technology is prospected, we believe Microwave Technology which will have broad application prospects, once industrialization can bring enormous economic and social benefits.

2. The mechanism and characteristics of microwave heating

Microwaves are a form of electromagnetic energy. You can change the ion mobility and rotation of dipoles, but does not cause changes in the molecular structure of non-ionizing radiation. Microwave usually refers to wavelengths of between 1 mm to 1 m (frequency 300-300000 MHz) electromagnetic waves, interposed between the infrared and the radio waves, and the most commonly used heating frequency is 2450 MHz. In general, the medium is heated in the microwave field. There are two mechanisms, namely ion conduction and dipole rotation. In the practical application of microwave heating, the microwave energy dissipation of two mechanisms exists.

2.1. Mechanism of ion transferring

Ion conductive electromagnetic field can move away from the conductive solution of ions, ion movement to form a current, due to the obstruction of the media and ion thermal effects [1-3]. All ions in solution from the conductive effect, but the effect size and media concentration and mobility of ions related. Therefore, the loss of ion transport microwave energy generated depends on the ion size, charge amount and conductivity, and is affected by the interaction of ions and molecules in solution.

2.2. Dipole rotation mechanism

Media is composed of many positively charged at one end, one end with a negatively charged molecule (or dipole) component. If the medium is placed between two metal plates, dipoles within the media as messy motion, when the DC voltage is applied to a metal plate, there is a DC electric field, dielectric dipole internal rearrangement between two poles formed. There are certain polarization oriented molecules regularly arranged. If a certain frequency of the alternating current into direct current, the electric field between the two poles will be alternately changed in the same frequency, medium fast swing corresponding dipoles in the 2450 MHz electric field and the dipoles to 4.9 × 109 times/s. fast swing speed. Due to thermal motion of molecules and interactions of adjacent molecules, so

Copyright © 2014 Jianhong Wang *et al.*
doi: 10.18686/esta.v1i1.5
Received: March 18, 2014; Accepted: May 26, 2014; Published online: July 28, 2014
This is an open-access article distributed under the terms of the Creative Commons Attribution Unported License (http://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
*Corresponding author: Water Treatment Institution, Nanjing University of Science & Technology, Nanjing, Jiangsu 210094, China. E-mail: wangjianhong186@sina.com

that the dipole change with the applied electric field direction and made subject to interference and obstruction rule when swinging, producing a similar effect of friction, so that chaotic motion of molecules gain energy to heat The forms, also will increase the temperature of the medium.

Relaxation time, temperature and viscosity dipole heating efficiency and related media. The mobility medium temperature and ion concentration and relaxation time of the medium determines the contribution of the two energy conversion mechanism of heat.

3. Waste gas treatment

With the development of modern industry, sulfur dioxide, nitrogen oxide emissions more and more. Sulfur dioxide in the atmosphere is the main source of acid rain, nitrogen oxides will destroy the ozone layer and can form photochemical smog, heavy metals and carbon particles are all humans and the whole ecological environment great harm. The use of microwave technology can handle nitrogen oxide and sulfur dioxide, while also effectively collect carbon particulates in the exhaust gas.

SO_2 and NO_x in the exhaust gas, in addition, there are a lot of N_2, H_2O, CO2 and O_2, these substances can be between 5-20 eV ionization and excitation of electrons can form an active group [4]. This high energy microwave frequency electromagnetic waves, can excitation and ionization N_2, H_2O, CO_2, O_2, forming HO, HO_2, N, H radicals and free electrons. HO, HO_2,O and reacted with SO_2 and SO_3 and NO_x generated NO_2. Therefore, you can use microwave energy is directly processed SO_2 and NO_x. Such as: D. Martin 2.45 GHz microwave use direct coal-fired flue gas SO_2 and NO_x, active group in the form of microwave radiation in combination with SO_2 and NO_x, SO_3 and generates NO_2, in water to form H_2SO_4 and HNO_3, achieve treatment purposes [5].

In addition, under microwave irradiation can be easily absorbed microwave radiation of a substance as a reducing agent in the exhaust gas treatment SO_2 and NO_x. Daxin Zhang, who simulated conditions in a laboratory experiment, a study without a catalyst by microwave. A new method processing carbon dioxide reduction technology, the research results show that: the removal microwave power and the type of reactor and the heating rate of sulfur dioxide large [6]. When the microwave is continuously applied, the sulfur dioxide removal efficiency up to 95%, in addition to sulfur dioxide and activated carbon products were characterized. Cha US company and the University of Wyoming joint use of easy absorption of microwave radio frequency energy activated carbon reductant in the role of RF energy field, the removal of coal-fired boiler flue gas SO_2 reduction not only makes success to elemental S, NO_x reduction to protect the air N_2, carbon is converted to CO_2, and the desulfurization rate of more than 95% [7]. Chang Yuicha and others to collect and destroy chlorine and nitrogen containing a wide range of volatile organic compounds [8] using a microwave. Volatile organic matter mineralization to H_2O and non-chlorinated CO_2, HCl chlorinated organics produced there. In the apparatus of adding equipment to absorb HCl. Meanwhile, the device can also be removed after the combustion gases SO_2 and NO_x. To purify the air, improve the quality of the atmosphere. This method and plasma method for flue gas desulfurization and denitration equipment compared with the simple, small one-time investment, simple operation, long life and other advantages, because they do not use catalysts, catalyst deactivation and poisoning and other problems do not exist. Therefore, the microwave processing technology will win broad market in natural gas, petrochemical, and other fields.

Because of carbon fine particles in the flue gas particle diameter is extremely small, about 0.01-0.2 μm, suspended in the air long-term, easy-deposited through the respiratory system in the human lung, highly carcinogenic. Foreign working on a microwave heating collect carbon particulate collector, when the carbon particles accumulate to a certain extent, it can automatically burn off, the collector filtering effect of carbon particles reach 60% to 90%, due to the carbon particles can be automatically combustion can be removed from the trouble of manual collection [9].

4. For solid waste disposal

Annual global industry generates a variety of oil-rich mud up to several billion t, if the traditional separation methods and landfill, the costly and occupy a considerable amount of landfill space. Therefore, the oil-rich sludge treatment and waste oil recycling research new technologies become a pressing global issue. To solve this problem, DA Purta Carnegie Mellon Institute of Pittsburgh and other environmental research center have developed oil sludge off the oil technology. The results showed that: microwave deoil treatment system 30 times faster than the conventional method, the system volume than conventional emulsion separation system 90% less. Imperial Petroleum Recovery Company R. Edward Peterson et al Purta technology base on the further development of the crude oil sludge removal technology [10]. The procedure is as follows: First, the original emulsion with microwave radiation, and then centrifuged in a continuous flow mode. The device processing capabilities of 283.5 L/min. Isolated high-quality oil, containing low amounts of water and solid pasty solid. Oil recovery was 98%, the residual solids can be landfilled.

Microwave technology also enables the construction waste recycling. According to reports, the United States CYCLEAN company uses microwave technology can be 100% recycled construction waste, recycled old asphalt road fabric, same quality with the new asphalt road fabric, and the cost can be reduced 1/3, while saving trash and handling and other costs, greatly reducing urban pollution [11].

Microwave radiation of certain solid waste drying and

sterilization. Yingwei Ding such as the use of microwave radiation drying animal excrement can improve the efficiency of agricultural animal manure as fertilizer, can kill pathogens, both to increase the income of aquaculture, and reduce agricultural pollution [12]. Alschuler and others to sewer feces into the microwave oven, microwave drying after combustion 45min, a bunch of pasty contaminants into a pile of clean, powdery ash [13]. Ikawa, who put a piece of contaminated cotton into the microwave oven, microwave sterilization can only 1 min up to 99% [14]. Therefore, the microwave technology for drying and sterilizing treatment of solid waste, not only to facilitate saving, and pollution, high efficiency.

Since the medical waste is toxic, it is difficult to be treated by a conventional method. Studies have shown that: microwave technology can be used on-site medical waste disposal, but also for waste transfer process [15,16]. Werner Curt et al found that many hospitals prior to the toxic waste disposal, the use of microwaves to sterilize them [17]. Under certain conditions, the medical waste after wet grinding, using microwaves to sterilize waste, toxins will be completely eliminated; the waste volume is reduced by 60% to 90%.

5. For sewage treatment

The microwave radiation technology to replace the traditional heating methods used to eliminate organic pollutants late 1980s, the rise of a new technology, which is characterized by fast, efficient, do not pollute the environment. The use of microwave heating characteristics, the microwave technology can be effective sludge processing and preparation of organic pollutants in environmentally friendly materials applied.

Organic pollutants in sewage treatment method is commonly used activated carbon adsorption, but the surface of activated carbon adsorption of organic matter, but difficult to handle. Microwave radiations effective desorption of organic carbon surface, activated carbon regeneration and facilitate digestion of organic matter and recycled. Studies have shown that: the use of microwave heating desorption degradability organic matter in sewage. As Zouzong Bo, who use microwave radiation to remove pollutants in wastewater Sulfosalicyl [18]. When waste water treatment, activated carbon adsorption of contaminants first, then charcoal filtered with microwave radiation, regenerated, can effectively eliminate the contaminated water of organic matter. Experimental results show that: Wastewater Sulfosalicyl removal 97.4%. Jin-Cheng Wang et al., In the presence of activated carbon under microwave irradiation enables Reactive Brilliant Blue KN-R solution rapidly bleaching, per g of activated carbon concentration of 300 mg/L of Reactive Brilliant Blue KN-R solution 50 mL, microwave 4 min, decolorization rate 97.1% [19]. The study also showed that due to the activated carbon under microwave irradiation treatment capacity Reactive Brilliant Blue KN-R was significantly higher than the saturated adsorption of reactive brilliant blue KN-R under the activated carbon at room temperature, indicating the presence of activated carbon under microwave irradiation enables reactive brilliant blue KN -R bleaching, in addition to the activated carbon adsorption, and can still lead to some chemical changes. G. Chih, who used the low energy of microwave radiation, and can absorb the sewage organic toxicants in granular activated carbon surface trichlorethylene, xylene, naphthalene and the like desorbed hydrocarbons and digestion, the final decomposition rate of 100%. The treated water is in long-term stability [20]. Also demonstrated microwave having the ability to degrade organic contaminants adsorbed on the surface of activated carbon. Satoshi Horikoshi, who at the same time by using microwave technology degradation TiO2 suspension after photo degradation rhodamine dye-B [21]. Because microwave irradiation greatly accelerate the hydroxyl radicals formed during the reaction and improve the surface activity of TiO_2, thus contributing to the degradation efficiency of rhodamine dye-B. Lixin Xia et al degradation when using microwave radiation technology polyvinyl alcohol (PVA), microwave power 800 W, irradiation time of 1 min, pH of 3, H_2O_2 dosage units of PVA is 0.22 g/g, 5 mL polyvinyl alcohol content of 7 % of the average degree of polymerization can be reduced to 67 [22] within 1 min. This will undoubtedly broaden the application fields of microwave radiation.

In the sewage treatment process, it can be used to replace conventional microwave heating the sludge dewatering and drying. Studies have shown that: microwave heating can be used to mechanically dewatered sewage sludge treatment, and the effect is particularly significant. Fu et al reported a large place, the undigested sludge wastewater treatment plant into the microwave oven heating 45 min, immediate effect is to reduce water content of sludge increased from 75% to 50% or less, low processing costs, and time is short, simple equipment [23].

Microwave in preparation of environmentally friendly materials mainly relates to the preparation of polyacrylamide flocculant (PAM), activated carbon sorbents and composite oil-absorbing body. Liwan Jie, who use microwave radiation preparation of polyacrylamide (PAM) [24]. They acrylamide solution using microwave heating, can be synthesized only 5 min PAM, PAM and for coal washing wastewater treatment effect compared to conventional heating method, flocculation strong adsorption capacity of pulverized coal particles, floc settlement rate, high water recoveries. Ning equality of people with microwave irradiation - the method of zinc chloride (ZCMR) take sawdust activated carbon, chromium-containing wastewater treatment research results show that: the sawdust activated carbon adsorption capacity, filtering speed, easy operation control, etc., activated carbon chromium The adsorption capacity is 1.72 times the level of commercially available powdered activated carbon adsorption capacity limit 21.5

mg/L, filtration rate of 1.64 times the commercially available activated carbon [25]. Jinhui Peng, who studied the microwave radiation through straw manufacture of activated carbon impregnated with zinc chloride, the results showed that: by microwave radiation 8 min, the resulting force of Methylene Blue decolorizing charcoal was 170 mL/g, a product of the national standard (LY216 -1979) of 1.42 times, the time compared to traditional methods of 1/45 [26]. Road Jianmei, who used the microwave synthesis of butyl methacrylate and acrylic acid β-hydroxyethyl acrylate copolymer complex oil-absorbing body and acrylate, 2-ethylhexyl acrylate and acrylic acid β-hydroxyethyl acrylate copolymer complex oil-absorbing body [27]. The effects of monomer ratio, initiator amount, crosslinking agent, various factors influence microwave radiation power high performance oil-absorbing composite body, which prepared the excellent performance of oil-absorbing complex.

6. For environmental monitoring

At present, the application of microwave technology in environmental monitoring is mainly microwave extraction and microwave disinfection. Microwave sample digestion, extraction aspect has been widely used in foreign countries.

The basic principle is to use microwave technology medium absorbs microwave energy level difference, by selecting different parameters of the solvent and adjusting the microwave heating of materials in the selective extraction of the target component, so that some of the organic constituents in the sample (such as an organic pollutant) aim to achieve with the matrix material isolated the active ingredient, microwave extraction has been used in the extraction and separation of soil and organic pollutants in sediment samples were extracted organic pollutants, including organochlorine pesticides, PCBs, phthalic esters. 1986, K. Ganzler et al reported the first use of microwave extraction of organic compounds from contaminated soil studies [28]. Microwave-assisted extraction of soil, sediments and other studies of organic contaminants is very active. Many papers published in recent years.

Results V. Lopez-Avila et al showed that: standard soil and sediment samples in a microwave extraction device (with pressure and temperature control systems, CEM production) of using n (n-hexane) tn (acetone) = 1t1, at 80 °c , 115 °c, extraction at 145 °c 5min, 10min and 20min. PAHs, OCPs and average recoveries of phenolic compounds is 65% to 85%, the same conditions, the extraction rate of 50% at room temperature [29]. V.Lopez-Avila, who believe MAE compared with the traditional Soxhlet or sonication extraction, significantly saving extraction time and solvent consumption. RCLao, who studied microwave assisted extraction of PAHs in environmental samples, and with the traditional Soxhlet extraction, mechanical shaking extraction results were compared in the commercial domestic microwave oven (Sanyo EM804T) in, 250 mL of cyclohexane mixed with PUF sample, the maximum power heated under 25 s, continuous operation five times, the recovery study aging 1 d, 6 d, 21 d of PUF in PAHs showed that in addition to the large molecular weight PAHs, the extraction rate greater than mechanical oscillations MAP extraction, aging 6d of PUF , MAP and Soxhlet extraction efficiency considerably.

H. Budzinski and others with focused microwave-assisted extraction system at atmospheric pressure to extract PAHs from the standard sample sediment and biological tissue research [31]. Under optimum conditions, the power is 30W, time was 10min, the extraction agent (dichloromethane 10–20 mL), water mass fraction of 20% to 30%, the extraction rate of 85% (compared with the standard value), with the traditional The Soxhlet extraction compared to substantial savings in extraction time and solvent consumption.

Fionuska et al conducted a sample study of microwave-assisted extraction of PCBs [32]. After 500 mL water sample +10 g NaCl +50 mL of isooctane was added after mixing tetrafluoroethylene sealed container, (70 ± 5) °c microwave treatment 2 min at full power, water cooled to ambient temperature, the above steps are repeated at least 5 times. With the traditional liquid-liquid extraction results (500 mL water sample was extracted with dichloromethane and 50 mL in 1 L separating funnel 2 min) quite. PCBs series material recovery of 68% to 85%, if the increase the extraction temperature reaches 100 °c, the recovery rate can reach 95%. The results showed that with Na_2Cl amount increases, the recovery rate has improved significantly. NaCl is added after the one hand, salting out effect plays an important role, while increasing the NaCl concentration, the water absorption capacity of the sample of the microwave in favor of increasing the extraction.

The use of microwave-assisted techniques to extract samples were analyzed for PCBs [33], [34] phenols, pesticides [35,36] the same herbicide has a high recovery rate, high selectivity, fast heating, easy temperature control and low solvent consumption, small equipment size, reduce pollution and waste products, such as a series of advantages. Visible, microwave assisted extraction will have a good prospect in analytical chemistry and get more people's attention.

7. Research prospect

Although the microwave technology application in the field of environmental protection is encouraging, but associated with fundamental research in general, or backward. To solve the problem of basic research, the key is based on the characteristics of electromagnetic waves, the impact of chemical reactions to be studied. Different difference frequency of the microwave to the same effect of the compound; Reaction results in the same type of chemical reactions at different microwave frequencies, to further

identify the relationship (on molecular structure) and the compound of microwave frequency between; molecular structure in a microwave changes in radiation, find microwave conditions affect molecular structure; the relationship between research and bond vibration frequency of the microwave, as well as the load of a certain frequency of the electromagnetic field of the microwave phase (modulation scheme) on the chemical bond. But also to investigate environmental conditions (such as the shape microwave cavity, the reaction vessel shape, temperature, etc.) relations with microwave chemical reaction effect. Thus revealing the existence of some in the microwave non-thermal effects, which can have a purpose in future studies. There is a direction to the microwave, microwave conditions starting to adapt to the design of the chemical reaction from the theory, and the reaction targets prediction. Reaction to achieve objectives such as the desire to predict that contaminants from water in the microwave process which, it is possible to recycle useful materials to offset part of the cost of sewage treatment, thereby reducing processing costs, its early industrialization. In addition, the application of microwave technology in the field of environmental protection is mainly based on its thermal effects. Therefore, accurate distribution of measured or calculated temperature field of the microwave field is particularly important, the accuracy of the temperature field measurements to improve the processing efficiency, control of microwave leakage and reduce the energy consumption of great significance. There is no one ideal method can accurately calculate the microwave field distribution of temperature field, the United States developed the H500 and H2900 design type and other laboratory dedicated microwave processor and it has greatly improved in terms of precise temperature control.

With the increasingly widespread application of microwave technology, whether the impact on human health problem it urgently clear. But the key is designed to prevent leakage of microwave reaction chamber. Sun Pingdeng people being studied using computer simulation to design microwave reaction chamber to reduce microwave leakage purposes. Even microwave leakage, the microwave absorbing material can also absorb microwaves and maximally converted into other forms of energy (mainly in the form of heat), and others such as Hu Kuo-kuang test confirmed that the fine iron ore processed electromagnetic wave 7–12 GHz band has greater absorption, could be a cheap absorbing material [38].

In summary, the microwave applications in the field of environmental protection with fast and efficient, simplify procedures, environmental resource recycling utilization, energy saving, low cost saving. Microwave technology in processing and there is great potential of the preparation of air, water, solid waste environmentally friendly materials, but it is also a good monitoring techniques. As we can pay attention to microwave leakage to harm people and their surroundings, and to control, while avoiding disadvantages. With the continuous development of people's attention to environmental protection and environmental technology microwave, we believe microwave technology will bring great industrial and social benefits.

Conflicts of interest

These authors have no conflicts of interest to declare.

Authors' contributions

These authors contributed equally to this work.

References

1. Mingos, D. M. P., & Baghurst, D. R. (1991). Application of microwave dielectric heating effects to synthetic problems in chemistry. *Chemical Society Reviews, 20*, 1–47.
2. Zlotorzynski, A. (1995). The application of microwave radiation to analytical and environmental chemistry. *Critical Reviews in Analytical Chemistry, 25*(1), 43–76.
3. Kingston, H. M., & Jassie, L. B. (1992). *Introduction to microwave sample preparation : theory and practice*. Guo Zhenku Beijing: China Meteorological Press.
4. Marek, A., & Wojtowicz. (2000). Control of Nitric Oxide, Nitrous Oxide, and Ammonia emissions using microwave plasmas. *Journal of Hazardous Materials, 74*, 81–89.
5. Martin, D. (1997). New method for removal of SO_2 and NO from combustion flue gases. *Journal of Microwave Power and Electro-Magnetic Energy, 32*(4), 215-218.
6. Zhang, D. X. (1998) Study of SO_2. *Treated Carbon Reduction Microwave Sinica, 14*(4), 341–346.
7. Zhou, Y. K. (1994). Microwave technology in flue gas desulfurization. *Chemical Environmental Protection, 14*(3), 148–152.
8. Chang, Y. C., Charlie, T. C. (2001). Microwave process for removal and destruction of volatile organic compounds. *Environmental Progress, 20*(3), 145–150.
9. Xie, S. (1999). Automobile exhaust pollution and control technology. *Machinery Development, 3*, 1–5.
10. Yang, Q. (2001). Microwave technology in environmental protection. *Environmental Protection, 1*, 41–43.
11. Tao, L. (1999). Present situation and utilization of the built environment. *Construction Technology, 28*(5), 44–45.
12. Wei, D. Y. (1998). Animal excretion of environmental pollution control measures. *Food and Feed Industry, 8*, 38–39.
13. Alschuler. (1992). Inventor plumbers microwave toilet. *Garbage, 5*, 14–16.
14. Ikawa. (1999). Reducing bacteria in household sponges. *Journal of Environmental Health, 62*(1), 18–23.
15. Gonzales. (2000). Hospitals adopting new methods of handling waste. *Sacramen to Business Journal, 16*(51), 22–24.
16. Yan, Y. H., & Bai, Z. P. (2000). Medical waste management and disposal methods. *Environmental Review, 3*, 19–21.
17. Werner, C. (1993). Hospitals using new medical waste disposal methods to save money. *Hospital Materials Man-*

agement, 18(7) 417–421.
18. Bo, Z. Z., Fu, D. T., & Zhang, L. (1999). Sulfosalicyl eliminate pollutants using microwave irradiation. *Environmental Pollution and Control, 21*(1), 22–24.
19. Wang, J. C., & Xue, D. M. (2001). Microwave radiation treatment reactive brilliant blue KN-R dye solution. *Environmental Science, 21*(5), 628–630.
20. Chih, G. (1998). Application of actived carbon in a microwave radiation field to treat Trichloroethylene. *Carbon, 36*(11), 1643–1648.
21. Satoshi, H., Hisao, H., & Nike, S. (2002). Environmental remediation by an integrated microwave/ uv-illumination method, microwave assisted degradation of Rhodamine-b dye in aqueous TiO_2 dispersions. *Environmental Science and Technology, 36*(6), 1357–1366.
22. Xia, L. X., Li, K. L., & Pang, J. (2000). Microwave radiation technology in polyvinyl degradation reactions. *Environmental Chemistry, 19*(6), 556–560.
23. Fu, D. D., & Tsai, M. Y. (1999). Sewage treatment plant sludge microwave test. *China Water Supply and Drainage, 15*(3), 44–46.
24. Li, W. J., & Ruan, L. (1999). Microwave field PAM synthesis and its application in coal washing wastewater. *Coal Conversion, 22*(4): 87–89.
25. Ninh, B., Peng, J. H., & Goh, P. (1999). Microwave Preparation sawdust charcoal and adsorption properties of Cr^{6+}. *Shanghai Environmental Sciences, 18*(2), 80–82.
26. Peng, J. H., Zhang, S. M., & Zhang, L. B. (2000). Microwave irradiation straw manufacture of activated carbon. *Environmental Pollution and Control, 22*(10), 1–2.
27. Lu, J. M., Song J. Q., & Li, Y. (1999). Oil absorption of microwave radiation. *Preparing Complex Chemical World Performance, 40*(2), 87–89.
28. Ganzler, K., Salgo, A., & Valk, K. (1986). Microwave extraction a novel sample preparation method for chromatograph. *Journal of Chromatography, 371*, 299–306.
29. Lopez, A. V., Young, R., & Beckert, W. F. (1994). Microwave assisted extraction of organic compounds from standard reference soils and sediment. *Chem, 66*, 1097–1106
30. Lao, R. C., Shu. Y. Y., & Holmes, J. (1996). Environmental sample cleaning and extraction procedures by microwave assisted process (MAP) technology. *Microchemical Journal, 53*, 99–108.
31. Budinski, H., Baumard, P., & Papineau, A. (1996). Focused microwave as sited extraction of polycyclic aromatic compounds from standard reference materials, sediments and biological tissues. *Polyticlic Compounds, 9*, 225–232.
32. Onuska, F. I., Terry, K. A. (1995). Microwave extraction in analytical chemistry of pollutants: polychlorinated biphenyls. *Chromatogr, 18*, 417–421.
33. Lopez, A. V., Benedicto, J., Charan, C. (1995). Deamination of PCBs in soil sediments by microwave assisted extraction and GC/ECD or ELISE. *Environ Scitechnol, 29*, 2709–2712.
34. Lopez, A. V., Young, R. A., & Cela, R. (1995). Accelerated extraction of organic pollutants using microwave energy. *Journal of Chromotographic Science, 33*(9), 481–484.
35. Onuska, F. I., & Terry, K. A. (1993). Extraction of pesticides from sediments using a microwave technique. *Chromatographia, 36*, 191–194.
36. Molins, C., Hongendoorn, E. A., & Heusinkveld, H. A. G. (1996). Microwave assisted solvent extraction (MASE) for the efficient determination of triazines in soil samples with aged resides. *Chromatogrphia, 43*(9/10), 527–532.
37. Sun, P., Xiao, B., & Yang, K. (2002). Microwave technology in environmental protection application. *Chemical Environmental Protection, 22*(2), 71–74.
38. Hu, K. K., Yao, X. P., & Yin, P. (1999). Study characteristics with iron ore produced ferrite microwave absorbent. *Functional Materials, 30*(3), 261–262.