GSCN was established in 2000 to promote research and development for the Environment and Human Health and Safety, through the innovation of Chemistry .

Efforts Required of Universities toward Environmental Problems

Yoshiko Arikawa
President
Japan Women's University

Any university campus uses a comparatively high amount of energy for workplaces in the area, and since energy use is closely related to carbon dioxide emissions and the problem of global warming, is required to find ways of reducing its consumption. The Law Concerning the Rational Use of Energy, targeted at reducing energy consumption among workplaces expending more than 1,500 kiloliters of crude oil equivalent a year, has been revised in 2010 to impose tougher restrictions on universities, adopting the unit of energy control per corporation instead of each university campus. Energy consumption at universities has tended to increase steadily due to the large number of facilities and long operating hours, as well as new construction projects, the development of information technology systems and greater demands on research.

In March 2010, the Ministry of Education, Culture, Sports, Science and Technology "A Manual of Good Practice in Energy Reduction for Managers and Administrators in Places of Higher Education," in which the Ministry has required the university authorities to "promote education and research that will give the university a leading role in society in countering the problems of high energy consumption and global warming," recommending that strategic systems led by the administration be developed throughout the university and environmental consciousness be fostered among employees and students. Moreover, the university is also following local government regulations and cooperating fully with regional measures to protect the environment.

As an educational and research establishment, the university aims not only to produce young adults who may become active in environmental problems, but also to train specialists in the field of environmental research. As someone whose own research has crossed into environmental science, I hope that the understanding students acquire of environmental problems through their education will at the same time encourage them to take an active part in the university's environmental policies.

"Microwave-assisted Polymerization Process"

National Institute of advanced Industrial Science and Technology(AIST)
Ritsuko Nagahata and Kazuhiko Takeuchi (Senior Research Scientists)

Microwaves are widely used in food, rubber, ceramics, and steel industries as energy source for uniform and rapid heating of materials. Their usefulness in accelerating rate and enhancing selectivity, applicability in solvent-free chemistry, and effectiveness in reducing production energy and CO_2 emission for organic synthesis reactions have been reported, but researches mainly are, however, still in the experimental stage. We tested the use of microwaves in the polymerization process, particularly in polyester synthesis, which uses a great deal of production energy, and succeeded in greatly reducing time and energy for production. Using these results, we developed an equipment for practical use in lactic acid polymerization.

Microwaves are electromagnetic waves with frequencies ranging roughly from 300MHz to 30GHz and are widely used not only in the field of radars and communications, but also, owing to their ability to heat materials rapidly, in various fields such as in heating and drying food, drying and sintering ceramics, drying of large monolithic refractories for steel, and vulcanizing rubber. Unlike traditional heating methods such as steam and electric heating where the material is heated from its surface by conduction, microwaves heat materials directly from the inside, enabling fast and uniform heating, efficient energy usage, and shortened heating time. In organic synthesis, use of microwaves enhances rate and selectivity of reactions and facilitates solvent-free reactions. In addition, use of microwaves greatly reduces energy and CO_2 emission during production, reduces environmental burden, and enables downsizing and simplification of manufacturing equipment. However, despite having wide-ranging advantages and being the subject of much research, most of the researches so far have not gone beyond desktop-scale verification testing (1).

Reports of applications of microwaves in polymer chemistry (addition, condensation, and ring-opening polymerization), citing shorter reaction times and better control of molecular structure, are plentiful (2). We have focused on condensation polymerization, a field of polymer chemistry where the features of microwave irradiation can be put to good use. In particular, we have chosen to work on polyesters, where practical applications can be developed faster. Polyester production involves multiple stages, high temperatures, and long reactions; thus, it involves a great deal of energy for production aside from often requiring the use of halogenated materials and solvents. Thus, the demand for developing a simple, economic, environment-friendly, and fast manufacturing method from the industry sector has been high.

Polyester synthesis is a polycondensation reaction that mainly involves substrates and desorption components that absorb microwaves well. First, as a model polymer, we tested synthesis of poly(butylene succinate) (Figure 1). We mixed equimolar amounts of succinate and 1,4-butanediol without using solvents and heated them by microwave after adding tin or titanium catalysts. Polymers with average molecular weights exceeding 100,000 were obtained after 75 min at 260 °C under reduced pressure conditions. We have achieved a one-step rapid polymerization that is not possible using oil baths and other conduction heating methods. Our method is applicable for various polyesters such as PET and polylactic acids. In particular, we obtained a polylactic acid polymer with molecular weight of 20,000 in one step without using lactide as intermediate through a direct polycondensation process. Polymers obtained through microwave heating are usually linear and have few heterogenous structures. Further, even during solvent-free synthesis, microwave heating enables significantly faster reactions compared to conduction heating methods. As such, its applications in medicine and other fields where the use of catalysts (impurities) is undesirable, are worthy of attention.

In an effort towards commercialization, last year, we developed the world's first ever a practical batch-type polymer synthesis equipment with an annual production capacity in the scale of a few tons. Initially, we started with commerical operation for producing polylactic acid for food, where we achieved a reaction rate many times higher than that of conventional methods and a reduction in energy for production up to more than 70% (3). In collaboration with two private companies, we are now aiming to develop a thousand-ton-class processing plant, even as we continue to explore large-scale machinery applications for microwaves.

Acknowledgement

This research was funded by the NEDO Grant for Industrial Technology Research (2006), the NEDO Practical Application of University R&D Results under the Matching Fund Method(R&D) Grant Program in 2009, and the GSC Project (2009). We also express our gratitude to Shikoku Instrumentation Co., Ltd., for developing and manufacturing the batch-type polymer production equipment, and to GLART Inc., for actively pursuing the commercialization process with us.

References

1. Wada, Takeuchi, *Microwave-assisted Chemical Process Technology*. CMC Publishing (2006).
2. Takeuchi, Nagahata, *PETROTECH,* **31**,564 (2008).
3. Nakamura, et al., *Org. Proc. Res. Dev*., **14**, 781 (2010).

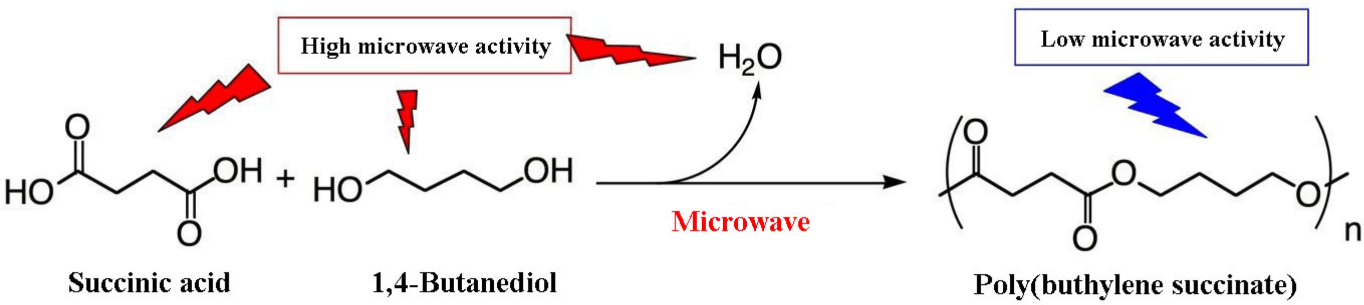


Figure 1 Synthesis of poly(buthylene succinate)

Environmental and Economic Impacts of Collection and Treatment of Plastic Waste

Nishihara Hajime
Plastics Waste Management Institute, Department of Research and Development

We studied the current situation of plastic waste management,with a consideration of its environmental and economic impacts, by surveying resource-recovery efforts and plastic waste collection in Tokyo's23 wards. Due to the high cost of collection and intermediate processing, resource recovery through materials recovery (material recycling [MR] and chemical recycling [CR])has higher economic burden than energy recovery (thermal recycling[TR]). The low loading capacity during collection for materials recovery results in high fuel consumptionandextended transportation mileage, resulting in overall increase in energy consumption, CO_2 emission, and economic burden.

PET bottles are collected in all 23 wards in Tokyo, but collection of foam trays, containers and packaging materials ("other plastics"), and non-packaging materials are different for each ward. These plastic wastes are divided into five groups (A to E) as shown in Table 1. Resource recovery methods for the different wards are classified broadly into energy recovery (Group A and E) and materials recovery (Group B and C). Wards that mainly collect and process"other plastic" wastesusing materials recoveryhave low environmental burden and high resource savings, but their economic burden is high. On the other hand, the opposite is true for wards that use energy recovery and mainly treat plastic waste as burnable waste (power generation efficiency: 13%). (Table 1; no available data for Group D)

Table 1 Status and evaluation of plastic waste management

Group	Proportion(Wt%)						Evaluation(basic unit)					
	Resorce recovery				Plastic waste collection		Resource conservation per kg			Environmental burden		Economic burden
	PET bottles	Foam Trays	Containers and Packaging (Other Plastics)	All plastics other than packaging	Burnable waste TR Power generation efficiency 13%	Non-burnable waste Landfilling	Crude oil equivalent L	Energy conservation MJ/kg	Proportion	kg-CO2/kg	Proportion	Proportion
A	7.7	0.4	0.0	0.0	85.5	6.4	0.168	6.49	基準 1.0	2.38	基準 1.0	基準 1.0
B	8.5	0.5	*12.1	0.0	69.3	9.5	0.237	9.16	1.4	2.03	0.9	1.3
C	7.5	0.0	**24.8	0.0	58.2	9.4	0.255	9.88	1.5	1.81	0.8	1.4
D	0	–	0	0	0	0	–	–	–	–	–	–
E	7.4	0.0	0.0	0.0	88.9	3.7	0.160	6.18	1.0	2.47	1.0	1.2

Crrude oil equivalent(L):values divided by crude oil heat release rate(38.7MJ/L)
* CR 100% ** CR/MR=74/26(CR/coke oven raw material)

To assess the resource recovery methods in more detail, the collection, transport, processing, and disposal processes were evaluated separately. In terms of environmental burden,recycling had the highest followed by collection, while intermediate processing, transport, and incineration had very low burden. In terms of economic burden, however, collection and intermediate processing had thehighest, accounting for more than half of the total costs. Figure 1 shows the detailed results of the assessment.

Energy consumption and CO_2 emission levels are shown on the y-axis; input of energy and its resulting CO_2 emission levels are shown on the plus side, while the amount of newmaterials for replacement that was avoided due to recycling (substitution product reduction) is shown in the minus side; their total value is marked with a shaded circle (). E conomic c osts w ere c ompared b y n ormalizing a gainst t he c ost f or burnable plastic wastes (assign value for TR as 1) and were classified into collection and intermediate processing (black part) and other processing (white part).

Cost-benefit analysis based on burnable waste collection and processing costs showed that recycling costs involved in collection and processing of “other plastic” wastes were equivalent to crude oil conservation costsof around five times the crude oil market value and CO_2 reduction costs of around 19 times the carbon emission trading price.

1) Resource conservation (reduction in crude oil equivalent)

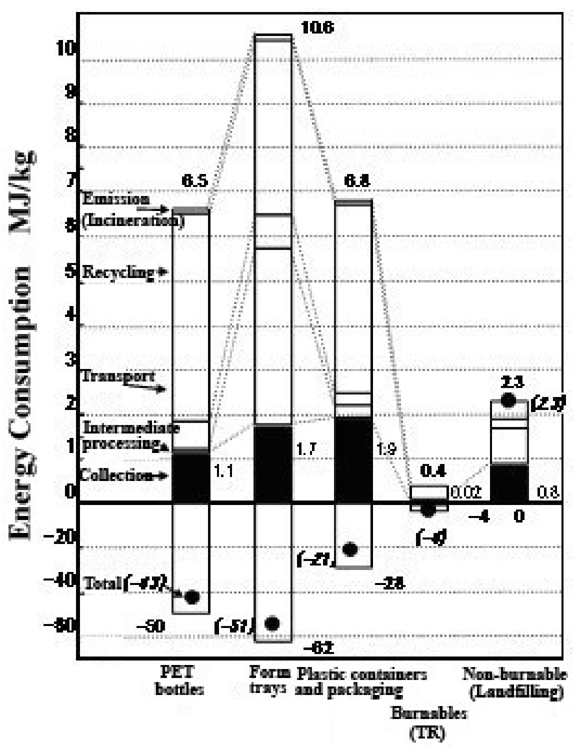
Based on Figure 1, the amount of energy conserved, which is the difference between the total energy consumption () for burnable plastic waste collection and processing (TR) and the total energy consumption for “other plastic” wastes, is 17.52MJ/kg, while the amount of reduction in crude oil equivalent, which is obtained by dividing the amount of energy conserved above by the crude oil heat release rate (38.7MJ/L), is 0.453L/kg.Figure 1 also shows that the economic burden for processing of “other plastic” wastes is 3.5 times the maximum cost of using the burnable plastic collection and processing (TR) system. Based on the actual reduction cost of 120 yen/kg incurred,the calculated cost for resource conservation is 265 yen/L.

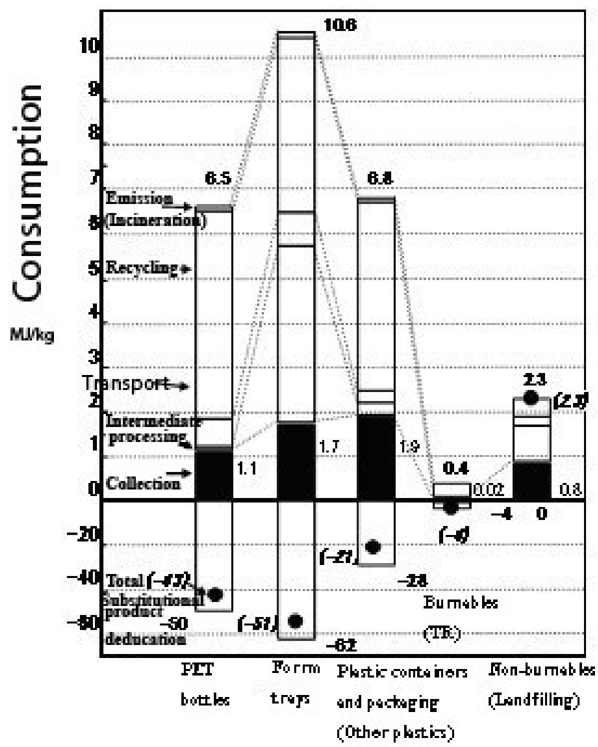
Assuming that one oil barrel (159L) is priced at 80 dollars (8000 yen), the economic burden for resource conservation for “other plastic” wastes, therefore, is around five times the crude oil market price (50 yen/L).

2) Reduction in CO_2 emission

As in (1) above, the amount of CO_2 reduction is2.06kg-CO_2/kgbased on the results in Figure 1. Based on theactual reduction cost of 120 yen/kg incurred, the calculated cost per kg-CO_2 is 58yen/kg. Assuming that CO_2 emission-trading price is 3 yen/kg, the economic burden for reduction of CO_2 emissions for “other plastic” wastes, therefore, is around 19 times the emission-trading price.

Reference: Research report on economic and environmental impact analysis of collection, transport, processing, and disposalof used plastics. Plastic Waste Management Institute, March, 2010.





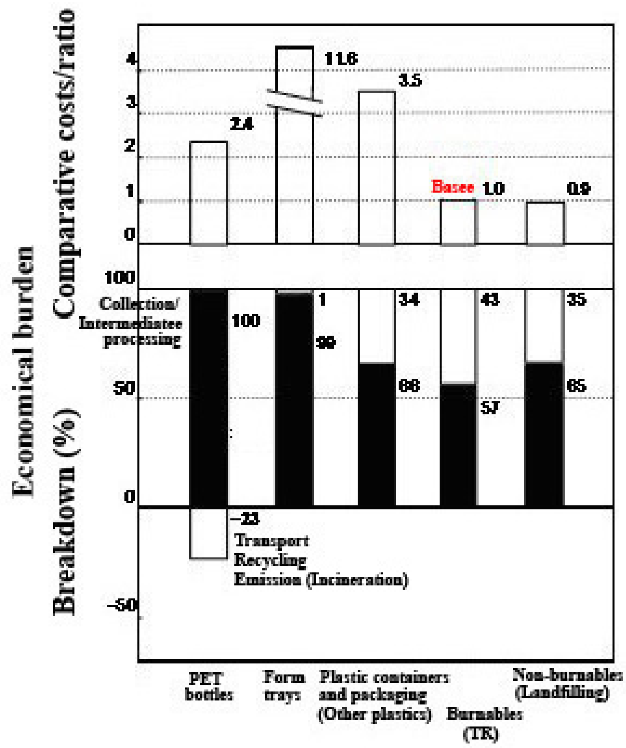


Figure 1 Analysis of the different processes involved in plastic waste management: relationship of resource conservation (energy consumption), environmental burden (CO2 emission volume) and economic burden.