



Environment and Society

Readings in Social and Environmental Studies



The Faculty of Social and Environmental Studies

Josai International University

Gumyo 1, Togane City

March 2015

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Preface

The Faculty of Social and Environmental Studies has established its educational goal as training global personnel who are of use in society by constructing “a sustainable society”, that balances society and the environment, under present circumstances marked by advancing global warming, the biodiversity crisis and other environmental issues that are appearing globally.

Our faculty, is making use of its characteristic as an international university, to establish “The Global College” Programme based on an “All English” policy as a new faculty, and providing our students with diverse opportunities to take a second foreign language such as Germany or French, in order to improve their linguistic skills that are the foundation of English education, and in this way to promote global education. Furthermore, by cooperating with more than 140 overseas sister universities, we are nurturing a viewpoint that considers the environment from a global perspective by deepening international exchanges with foreign students and understanding of overseas cultures through short and long term overseas study and student exchanges.

This textbook is an English summary of some of the results of education and research by our faculty edited mainly for students from abroad studying in our university to give them an accurate understanding of the contents of the education and research on the environment supplied by our faculty.

To our great honour., Professor Inoue, a member of the Japan Academy and Director, International Institute of Green Materials, JIU, has contributed three latest articles in English, Professors Lemkow, has contributed an article written in English. The categories under which we have arranged the writings included here are designated the chapter title. We have added *carmina arborea* as a local oral historian’s narrative on the environment near our campus, located in Gumyo, Chiba Prefecture.

Thanks go to the colleagues leading the joint project and the contributors to this collection.

31st March 2015

Hiroataka Suzuki

Dean

The Faculty of Social and Environmental Studies
Josai International University

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I. Environmental Sociology

Environment and Society: from Environmental Determinism to Environmental Governance

Louis Lemkow

1. Introduction

The term sociology was first used and defined by the French philosopher Auguste Comte in 1838. Sociology was to be the new science of society, replete with “laws” which would describe, explain and even predict the outcome of social processes. Such laws would be a direct parallel with those developed in the natural sciences. While Comte was one of the founders of the modern discipline of sociology which was consolidated in academia during 19th and 20th Centuries, attempts to understand the workings, structure and nature of human communities had formed part of western thought from at least as early as classical Greek society. Plato and Aristotle, to name just two key philosophers of the classical period, were both committed to studying and understanding the societies in which they lived.

Environmental sociology is one of the newest sub disciplines of sociology, centered as it is on the study of the interaction between environment and society. Its emergence as an area of academic research responded to the political activism and new social movements of the 1960s and 70s which denounced the degradation of the environment and the existence of an ecological crisis related to human productive and consumer behaviour. As with its parent discipline of sociology, concerns to understand the interaction between environment and society predate the creation of the sub discipline. The relationship between society, its structure, social organization and culture and the physical/biotic environment in which it is embedded has represented one of the important analytical concerns of scholars in the past - indeed, we can once again trace this area of intellectual enquiry back to classical Greek society and in particular to the writings and researches of Hippocrates of Cos who lived in the 5th Century BC.

This chapter shows how in western thought, our view of the environment society dialect began with the simplistic notion that our society and associated culture are the direct product of environmental and geographical factors. As society and economy were transformed by human agency, our environment in consequence was also changed and sometimes severely degraded. In this context the impact of human activity on the environment became the focus of concern of

scholars and the wider society. The globalization of the world's economy and culture and accelerated techno-industrial development and exploitation of the planet's resources saw a growing disquiet about the sustainability the Earth. Climate change, an outcome of the anthropogenic causes of environmental deterioration has lead scholars and environmental activists to conceive humanity's relationship with the environment in the framework of complexity. We have moved from a simplistic view of the environment-society connection to a recognition that the interaction between social and ecological systems are immensely complex. This chapter looks at how it was thought that our lives and culture were governed by the environment to the current urgency of developing effective and global environmental governance in the face of the severe impacts of human activity on the planet.

2. Environmental determinism: society and culture governed by nature

While Hippocrates is best known for his work on medicine, including the impact of geographical and environmental factors on human health, he also contributed to the notion that the environment seemed to play a relevant role in determining the nature and culture of human communities. Geographical or environmental determinism of which Hippocrates is probably the first coherent exponent in western thought represents a simple model of unidirectional causality: society is molded by its physical and biological setting. This vision or paradigm was extraordinarily persistent. It managed to survive the arrival of Christianity and Islam and the profound economic changes from the late middle ages onwards. It was found in the "progressive" writings of the French Philosophes of the 18th Century and in academic geography and anthropology of the following century. It was not seriously challenged as a theory of society and culture until the fin du siècle. Here is what Hippocrates had to say about the shaping of human cultures by the environment:

When a people lives in a rough mountainous country at a high elevation, and well watered where great differences of climate accompany the various seasons, the people will be of large physique, well accustomed to hardihood and bravery, with no small degree of fierceness and wildness in their character. On the other hand, in low-lying, stifling lands, of meadows.... They are phlegmatic rather than bilious. Bravery and hardihood are not an integral part of their characters although these traits can be created by training. (Hippocrates (1984), p. 67)

Simplistic, with naïve clichés perhaps, but Hippocrates was trying to explain the cultural diversity present in the part of the world in which he travelled and knew so well; the eastern Mediterranean. His answer was that it was largely the physical environment which determined the nature of cultural behavior and the “personality” of peoples and communities.

Organised monotheistic religion in the form of Christianity came to dominate the development of western thought well before the fall of Rome. While the notion of the “designed” world, that is to say “the Earth as a habitable planet which served men” (Glacken) was clearly central to Judeo-Christian (and later Islamic) thought, the idea of environmental or geographical determinism or influence remained as the framework for explaining the diversity of societies and cultural practices. It is striking how little this vision of societies molded by their physical and climatic environment remained unaltered until industrialization.

Writing over a millennia after Hippocrates, St. Thomas Aquinas (1224-1274) merely repeats the most vulgar form of determinism when trying to explain such an important social phenomenon: war.

A temperate climate is most conducive to fitness for war by which human society is kept in security. For as Begetius tells us, all people that live near the sun and are dried up by excessive heat have keener intellects, it is true but they have less blood, and consequently have no constancy or self-reliance... On the other hand northern tribes, far removed from the burning rays of the sun, are more dull-witted, indeed, but, they are ever ready for war. (Aquinas in Glacken (1976), p. 29)

In contrast to Aquinas and other Christian thinkers, was the contribution of Ibn Khaldun (1334-1406) and other philosophers living in the Islamic world. His contributions are considered important in history, philosophy, anthropology and geography. While obviously influenced by the Hippocratic corpus and classical learning in general, he was able to provide a more sophisticated analysis of the relationship between society, culture and the environment. His most important and celebrated work the “Muqadimah” examines, amongst other things the distribution of cultures in the then known world. While still maintaining the importance of physical geography and in particular climate as a central basis of culture he also shows how the biographies or histories of individual societies are important variables in explaining their cultures. Nevertheless Ibn Khaldun’s geographical determinism remained very prominent in his work as was the strong influence of classical Greek scholarship as we can see from the passage below:

The fifth, fourth, and third zones occupy an intermediate position. They have an abundant share of temperance, which is the golden mean. The fourth zone, being the one most nearly in the center, is as temperate as can be.... The physique and character of its inhabitants are temperate to the (high) degree necessitated by the composition of the air in which they live. (Khalidun (1989), p 311)

Another leap in time takes us to the “enlightenment” and one of the best known exponents of environmental (and particularly climatic) determinism: Montesquieu (1689-1755). Montesquieu’s “The Spirit of the Laws” examines political systems from a comparative perspective, and while widely criticized for its environmental determinism, it is still regarded as a “classic” in the field of political and legal sciences. Montesquieu’s thesis is: climate determines the character or “personality” of a people or nation and this in turn determines the organization or structure of society. Social structures determine the nature of laws. In the quote below we can see how Montesquieu tries to convince the reader with the new scientism of his times by showing that heat and cold have a physiological effect on crucial organs of the body, which determine individual behaviour and personality. From the supposed psychology of the individual located in a given climate, he extrapolates on the character of a whole nation. He tells us of an experiment he undertook on a frozen and unfrozen sheep’s tongue and its implications:

This observation confirms what I have been saying, that in cold climates the nervous glands are less expanded: they sink deeper into their sheaths, or they are sheltered from the action of external objects; consequently they have not such lively sensations.

In cold countries they have very little sensibility for pleasure; in temperate countries, they have more; in warm countries their sensibility is exquisite. As climates are distinguished by degrees of latitude, we might distinguish them also in some measure by those of sensibility. I have been in the Opera in England and Italy, where I have seen the same pieces and performers; and yet the same music produces such different effects on the two nations; one is so cold and phlegmatic and the other so lively and enraptured, that it seems almost inconceivable (Montesquieu (2011), p 223)

Alexander von Humboldt’s work, marks a turning point in relation to environmental influence. In his considerable output we can find a serious and

argued notion of “reciprocity” in terms of humankind’s relationship with the environment. While it is clear that he still accepted environmental influence, his adherence to it is qualified and rarely overstated. It can be argued that he has a rather “ecological” view of the complex interactions between environment and society.

The influence exercised upon man by the forces of nature, and the reciprocal, although weaker action which he in turn exercises on these natural forces. Dependent, though to a lesser degree than plants and animals, on the soil and meteorological processes of the atmosphere with which he is surrounded – escaping more readily from the control of natural forces, by activity of mind, and the advance of intellectual cultivation, no less than by his wonderful capacity of adapting himself to all climates. Man everywhere becomes most essentially associated with terrestrial life. (Humboldt (2013), p 360)

In the emerging academic social science, attention was given to the study not only of the social implications of industrialization but also to the environmental dimension as it impacted on the lives of communities. The geographer Elisée Réclus was quick to point out the relationship between economic processes and environmental changes induced by these human activities.

The action of man is a powerful agency in draining marshes and lakes, in smoothing down the obstacles between different countries, and in modifying the primitive distribution of animals and plant species, that these facts become of decisive importance in the changes which the outward surface of the globe is undergoing. The action of man may embellish the earth, but it may also disfigure it; according to the customs and social condition of any nation, it contributes to the degradation or glorification of nature. Man moulds into his own image the country which he inhabits. (Réclus, E., in Peet (1978/2003))

One of the most emblematic figures of academic environmental or geographical determinism of the Fin de siècle was the American geographer Ellen Semple (1863-1932). Her adherence to the environmental paradigm has no clearly expression in her masterly book “The Influence of the Geographic Environment” (1911). The following extensive quote illustrates Semple’s mastery of language and also her great clarity of thought (though it may be faulty). It must surely be one of the finest and most dazzling openings to any book dealing with geographical

matters and probably the clearest and most articulate presentations of the determinist argument:

Man is a product of the earth's surface. This means not merely that he is the child of the earth, dust of her dust; but that the earth mothered him, set him tasks, directed his thoughts, confronted him with difficulties that have strengthened his body and sharpened his wits, given him his problems of navigation or irrigation, and at the same time whispered hints of their solution. She has entered into his bone and tissue, into his mind and soul. In the mountain she has given him leg muscles of iron to climb the slope; along the coast she has left these weak and flabby, but given him instead vigorous development of chest and arm to handle paddle or oar. In the river valley she attaches him to the fertile soil, circumscribes his ideas and ambitions by a dull round of calm, exacting duties, narrows his outlook to the cramped horizon of his farm. Up on the wind-swept plateaus, in the boundless stretch of grasslands and the waterless tracts of the desert, where he roams with his flocks from pasture to pasture and oasis to oasis, where life knows much hardship but escapes the grind of drudgery, where the watching of grazing herds gives him leisure for contemplation, and the wide ranging life a big horizon, his ideas take on a certain gigantic simplicity; religion becomes monotheism, God becomes one, unrivalled like the sand of the desert and the grass of the steppe, stretching on without break or change. Chewing over the cud of his simple belief as the one food of his unfed mind, his faith becomes fanaticism; his big spatial ideas, born of that ceaseless regular wandering, outgrow the land that bred them and bear their legitimate fruit in wide imperial conquests. (Semple (2005), p 1-2)

In the case of the above passage there are really too many exceptions to Semple's rule relating pastoral nomadism to allow for such extravagant and overblown generalization. The "golden age" of environmental determinism was about to come to an end. As the contemporary British sociologist, Anthony Giddens has pointed out:

At a certain point, however – very recently in historical terms – we started worrying less about what nature can do to us, and more about what we have done to nature. (Giddens (2000), p. 44)

3. Industrialisation and environmental change and implications for governing the damage

A watershed in terms of our perception and study of the relationship between environment and society can be located in the industrial revolution, where it became clear that humans were changers of the environment and not simply influenced by it. The environmental impact of accelerated industrialization with its new forms of production involving the intensification and massification of the productive process were patently visible in the form of “smogs” and grossly polluted rivers. The negative impacts on human health were incontrovertible. The anthropogenic causes of the degradation of the environment became evident. Commentaries on the impacts of industrialization were to be found in many forms, including fiction such as Charles Dickens’ *Hard Times*:

It was a town of red brick, or of brick that would have been red if the smoke and ashes had allowed it; but as matters stood, it was a town of unnatural red and black like the painted face of a savage. It was a town of machinery and tall chimneys, out of which interminable serpents of smoke trailed themselves for ever and ever, and never got uncoiled. It had a black canal in it, and a river that ran purple with ill-smelling dye, and vast piles of building full of windows where there was a rattling and a trembling all day long, and where the piston of the steam-engine worked monotonously up and down, like the head of an elephant in a state of melancholy madness. It contained several large streets all very like one another, and many small streets still more like one another, inhabited by people equally like one another, who all went in and out at the same hours, with the same sound upon the same pavements, to do the same work, and to whom every day was the same as yesterday and to-morrow, and every year the counterpart of the last and the next. (Dickens (1998), p 19)

In a similar vein Freiderich Engels dissected the social, economic and environmental dynamics and changes introduced into England during its process of industrialization which began in the late 18th century. Writing about Manchester he states that:

At the bottom flows, or rather stagnates, the Irk, a narrow, coal-black, foul-smelling stream, full of debris and refuse, which it deposits on the shallower right bank. In dry weather, a long string of the most

disgusting, blackish-green, slime pools are left standing on this bank, from the depths of which bubbles of miasmatic gas constantly arise and give forth a stench unendurable even on the bridge forty or fifty feet above the surface of the stream. But besides this, the stream itself is checked every few paces by high weirs, behind which slime and refuse accumulate and rot in thick masses. Above the bridge are tanneries, bonemills, and gasworks, from which all drains and refuse find their way into the Irk, which receives further the contents of all the neighbouring sewers and privies. (Engels (2009), p.49)

Engels pointed out that the distribution of environmental aggressions was related to the new morphology of the industrial cities and was closely related to social class. Air and water pollution in the early industrial environment of Britain was a particularly localized phenomenon (geographically and socially) and one which impacted especially on the working class districts in its most severe form and again referring to Manchester and its hinterland he points out that:

The upper bourgeoisie (live) in remoter villas with gardens in Chorlton and Ardwick, or on the breezy heights of Cheetham Hill, Broughton and Pendleton, in free, wholesome country air. (Engels (2009), p. 45)

These conditions then, affected above all the new working class which emerged out of the industrial revolution along with new and highly visible social inequalities. The negative health outcomes were of particular concern and were described and denounced as part of the unacceptable contribution of industrialization:

That the various forms of epidemic, endemic, and other disease caused, or aggravated, or propagated chiefly amongst the labouring classes by atmospheric impurities produced by decomposing animal and vegetable substances, by damp and filth, and close and overcrowded dwellings prevail amongst the population in every part of the kingdom....that such diseases...is always found in connection with the physical circumstances above specified and that where those are removed by drainage, proper cleansing and other means of diminishing atmospheric impurity, the frequency and intensity of such diseases is abated. (Chadwick (1842), p. 369)

The discussion on inequalities and health has recurred in modern society, although it has been particularly associated with the analysis of industrialisation and urbanisation. The literature on this subject is vast and spans well over a century, focusing on the social and environmental determinants of health in the European industrial cities. The variables examined to explain the ill health and high mortality of the working class and the socially vulnerable included: air and water pollution, housing conditions, migratory processes, population density, diet and income. Classical indicators such as mortality were used to emphasize the massive differences in health between deprived and advantaged communities in the cities.

Most accounts, whether analytical or fictional, agreed that the environmental degradation of specific areas of the city mainly affected the already socially vulnerable and economically weak groups. In other words, urban environmental conditions inflicted the most harm on working-class neighbourhoods and communities. Other social classes were, in general, more fortunate. These unacceptable inequities in health, based as they were largely on the socio-economic and environmental circumstances of different groups and classes in society was denounced as a flagrant case of social injustice which should be remedied. It is more than ironical that the industrial revolution, made possible through the gross exploitation and pillaging of colonies through the imperial system would also result in the effective exploitation of the new working class at home and begin a process of massive environmental degradation which would severely impact on the most vulnerable communities while at the same time spark off global climate change which more than a century down the line we are today having to confront with urgency. The burden and impact of these environmental processes have in the past and will in the future be born by the socio-economically most vulnerable and is an example of social and environmental injustice.

It is often forgotten, that in the face of problems created through the environmental aggressions caused by the industrial revolution that there were organised efforts to reverse the trend by trying to regulate and diminish the sources of industrial pollution. The governance of environmental problems became part of the political agenda. Reformist and rogressive forces, including the trade unions and philanthropic associations would call for the intervention of the state to regulate, control and redress the manifest inequities. However the whole notion of state intervention was anathema to some influential political currents in society which were articulating their arguments against state intervention at the turn of the century on the basis of the crudest form of pseudoscientific social Darwinism

and biological reductionism. For these ideologues, men and women could not escape their their biological destinies. It was considered positively dangerous to attempt to do so because tampering with natural selection by protecting so-called weak individuals, groups or classes and institutions would inevitably lead to decadence and decline. Inequity was deemed to be natural. In applying Darwinian evolutionary theory to the social world, it was argued that all that implied state planning was inherently dangerous because it went against nature and could lead to the weakening of the nation and in particular, humanity as a whole. Every act of government intervention that fomented social assistance effectively supported the weak (who were to blame for their condition) and whose undesirable and unfit characteristics would normally be selected out of existence. The British sociologist Herbert Spencer in his *Man versus the State* was all too clear in his view and radical opposition to state interference:

If the benefits received by each individual were proportionate to its inferiority Progressive degradation would result. (Spencer (1969), p. 136)

In contrast to the above other sections of society and the academic community regard the role of intervention as a key to the policy for achieving greater social equity by reducing inequalities especial in relation health. The Welfare state has been the corner-stone of western European states in the effort to reduce health inequalities through universal health-care for all and has represented one of the great achievements of the reform era immediately following the Second World War. The objective was precisely to undo injustice of health inequalities, especially in relation to the most vulnerable groups which were frequently excluded from access to health care because of a lack of income. A direct parallel can be drawn between the struggle to reduce health inequalities and the current moves to overcome environmental and social injustice generated by global climate change.

As we have already pointed out, environmental degradation during the industrial revolution hit working class communities the hardest and in that sense it discriminated against the most vulnerable group and affected in particular the quality of their lives and especially their health. As we move into the 20th Century, the dynamics of environmental degradation began to change in important ways. It was the American biologist and writer Rachel Carson in her brilliant and hugely influential “bestseller” *Silent Spring*, published in 1962 who first pointed out the way in which new pollutants could contaminate the whole biosphere. The globalising environmental hazards which she described were very different from

the much more localised impacts of environmental problems of the industrial revolution which affected most directly the new working class. In the chapter, “Elixirs or Death” she tells us:

For the first time in the history of the world, every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death. In less than two decades of their use, the synthetic pesticides have been so thoroughly distributed throughout the animate and inanimate world that they occur virtually everywhere... They have been found in remote mountain lakes, in earthworms burrowing in the soil, in the eggs of birds – and in man himself. For these chemicals are now stored in the bodies of the vast majority of human beings regardless of age. They occur in the mothers’ milk and probably in the tissues of the unborn child. (Carson (1962), p 15-16)

She presented a bleak picture of our future environment – the environment of all men, women and children regardless of their social position in society. No one would escape the consequences of the “ecological disaster being perpetrated by the use of synthetic chemicals such as DDT. The book was published as a paperback and was a bestseller for months – it had entered the living rooms and discussions of middle class America and was soon to do the same in Western Europe.

These new environmental hazards which Rachel Carson mentioned, were not visible in the dramatic form of the smogs of the industrial revolution, but appeared to be more insidious and potentially more destructive and dangerous. Furthermore, because of their tendency to accumulate and spread throughout an ecosystem and up the food chain, they were capable of affecting groups which hitherto had come out relatively unscathed from the worst environmental effects of industrialisation. These new groups, and especially the middle class began to feel vulnerable and insecure in the face of the qualitative changes taking place in the environment. This new awareness and feeling of insecurity had a lot to do with the emergence of environmental movements of the late 60s and during the 70s, which were very much lead and inspired by middle class activism. Environmental political action also began to incorporate concerns relating to the imminent scarcity of crucial natural resources and the need to attain planetary sustainability.

Industrializing countries were changers of the environment (pre-capitalist societies also impact on the environment, although on a very different scale).

Human beings have always been invasive, but the role of invaders of territory and the environment along with the plundering of natural resources became part of the process of industrialization. Securing access to vital natural resources necessary for the continued growth of industrial capitalism and became an imperative and led to the acceleration of imperial conquests in regions distant from the homeland of the industrial nations. Associated with industrialization was rapid population growth, which in turn placed more pressure on guaranteeing access to precious resources. In this context a new concern appeared on the stage; whether the planet as a whole could continue to sustain population growth and resource depletion. Scarcity and sustainability were to form part of a narrative which began to contest the imperative of unlimited economic growth. Sustainability has many implications in terms the future structuring of the economy and society as well as the way in which politics is practiced.

4. Climate change, sustainability and risk: governance in complexity

If climate change is about the complex relationship between environment and society and the emergence of new risks in the framework of modernization, then sustainability is about intergenerational solidarity; that is to say it is about framing our present actions and activities in terms of the welfare and wellbeing of future generations. Caring for the quality and health of the environment almost invariably involves policy making which integrate and recognise the complexity of social and ecological systems while at the same time taking a long term view, spanning and influencing the lives of more than one generation. Overcoming the problem of global climate change is very much an intergenerational issue which involves analysing, planning and policy making for a period which will take us to the end of this century.

Climate change manifested by atmospheric warming and the “greenhouse” effect is probably the clearest representation of the globalisation of environmental risks and of what the German environmental sociologist, Ulrich Beck, termed the “risk society” (Beck (1992)).

"In contrast to all earlier epochs (including industrial society), the risk society is characterized essentially by a lack: the impossibility of an external attribution of hazards. In other words, risks depend on decisions, they are industrially produced and in this sense politically reflexive'. (Beck (1992), p. 183)

Giddens points to the importance of “manufactured risks” related to new scientific knowledge and technological applications as well as to the process of globalisation:

Risk created by the very impact of our own developing knowledge upon the world.....most environmental risks, such as those associated with global warming...are directly influenced by the intensifying globalisation...(Giddens (2000). p. 44)

Global climate change contains all the ingredients of what are known as “new environmental risks” and which have spread globally since the middle of the last century; climate change is on a planetary scale; it has much to do with accelerated techno-economic change at the level of production and consumption; it is difficult to detect, measure and control; it impacts on all social groups, but most importantly it accumulates and hits the most socially and economically vulnerable groups in our society; future scenarios for climate change and the outcomes in the medium and long term are uncertain (even the scientific community doesn’t agree about the range and depth of climate change impacts on the planet) and above all, in large part, the causes of current climate change are related to human action.

All these notoriously complex elements have generated concern and a sense of insecurity, especially, but not exclusively in the most economically developed societies with the highest living standards, the societies which have precisely contributed most to the causes of climate change through processes of rapid industrialisation and mass consumption patterns largely initiated in the first half of the 19th Century in Western Europe and United States of America and much more recently in north east Asia. Public anxiety and concern has been endorsed and represented by the mass media and in part this has contributed in situating climate change at the centre of the international political debate and on the agendas of governments and intergovernmental institutions. The political and social responses and the involvement of society particularly through the intense activities of NGOs has resulted in the articulation of policy proposals for mitigating climate change which necessarily involve all nations – nations which are highly differentiated from one another in terms of social and economic structure and wealth and which have very different priorities and political agendas. These structural differences, which have a great deal to do with the now very tense and strained international negotiations on global climate change where the issues of social justice, inequalities and vulnerability, have begun to play centre stage.

It should be mentioned that some scientist warned of the effects of human activity on climate well over a century ago and that it was very plausible to postulate the idea increasing global temperatures because of very rapid

industrialisation based on the intensive use of fossil fuels as its principle energy source which represented the origin of much higher carbon dioxide emissions. The best known of the early warnings was made by the Swedish Nobel laureate Svante Arrhenius in 1896 in his article “On the influences of Carbonic Acid in the Air upon the Temperature of the Ground” in which he made the conjecture that as CO₂ increased geometrically in the air, temperatures at sea-level would increase arithmetically – doubling CO₂ would result roughly in a 1° temperature increase. It is worth noting that his predictions do not differ very substantially from those of the IPCC (Intergovernmental Panel on Climate Change. However he felt that the contribution of CO₂ to the atmosphere as a result of industrialisation would be positive because it would allay the effects of a coming period of glaciation. The writer, scientist, and essayist H. G. Wells not averse to making extrapolations about future scientific and societal changes writing in 1922 opted for a prudent approach to climate change arguing that it was necessary for more scientific data and empirical evidence before a clear statement could be made:

“But we do not know sufficient of the causes of climatic change at present to forecast the possible fluctuations of climatic conditions that lie before us... we lack sufficient science.” (Wells (1922), p 36)

The scientific evidence was soon to emerge. Systematic measurements of atmospheric CO₂ taken at Mauna Loa, Hawaii beginning in the 1950s demonstrated a clear increase of this and other greenhouse gases and which seemed to be related to the rapidly growing use of fossil fuels for a whole host of industrial, domestic and other activities giving rise to the hypothesis of the “greenhouse effect”. Little by Little during the 1960s and 70s the premise about the relationship between industrialisation and global warming became consolidated in scientific circles in the context of increasing public concern about globalising environmental hazards so eloquently denounced in Rachel Carson’s “bestseller” *Silent Spring*.

The response by international organisations as a result of initiatives and pressures from the World Meteorological Organisation and the United Nations Environment Programme was to eventually (“better late than never”) create the Intergovernmental Panel on Climate Change (IPCC) in 1988 coinciding with the hottest year of the XXth Century (up until that year). The IPCC published its first report two years later. The objectives of this and later reports were to:

Assess periodically the science, impacts and socio-economics of climate change and of adaptation and mitigation options The long-term

nature and uncertainty of its driving forces require scenarios that extend to the end of the 21st Century ...scenarios cover a wide-range of main driving forces for future emissions, from demographics to technological and economic developments.

Socio-economic issues were being addressed as was the sensitive and complex issue of economic development. The reports clearly vindicated the notion of human induced climate change while admitting that there were many uncertainties in making forecasts. The reports were to also provide a tool for policy makers to propose and formulate responses to global climate change. The logic and urgency of this situation resulted in the creation of a dynamic of international conferences to tackle global climate change under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). The first convention, the so-called "Earth Summit" was held in Rio de Janeiro in 1992 and was followed as of 1995 by a series of "Conferences of the Parties" (COP) on a yearly basis and includes the Kyoto COP 3 meeting held in 1997 when the Kyoto Protocol was signed.

Global environmental change in the context of the greenhouse effect have considerable implications for our planetary future in the medium (now soon to become short) and long term - the impacts will be felt most in specific and socially and geographically vulnerable parts of the world and felt by very concrete collectives and communities. While scientists debate about the complex details of climate change scenarios there is consensus that there will be an increase in "extreme climate events" as ocean temperatures gradually rise (along with sea-level). Oceans are reservoirs of energy and as there will be more energy in the ocean/atmosphere system, then more frequent and violent meteorological phenomena will occur in the form of torrential rain, hurricanes and droughts with the resulting damage to those communities affected. It is very well documented the differential impact of extreme climate events in terms of how these effect societies according to their socio-economic status; death and destruction are infinitely more devastating in poorer regions compared with rich and developed ones. Rising sea levels and droughts will generate environmental migrations as they have in the past in the face of ecological change/disasters (take for example the migrations from the Aral Sea area in Central Asia - a sea which almost disappeared as a result of the thoughtless and gigantic irrigation policies and programmes of the former Soviet Union).

It should not be forgotten, of course, that within even the most economically developed countries great social inequalities exist. While the USA has a huge GDP, it also has huge inequalities. The USA, the society which consumes 20% of the

world's fossil fuels with its resulting emissions and contribution to global warming will not be left unharmed by climate change, however it will be precisely the result of social inequalities that climate change will inflict greatest damage on the socially vulnerable areas and people of the United States. Western Europe will also not be unscathed and again largely because of the many different dimensions of inequality which exist in the continent. We already have a great deal of documentation on, for example the impacts of flooding and heat-waves in Europe (both of which are expected to increase as a consequence of climate change). There are no great surprises here in terms of the discriminatory nature of these impacts; vulnerability being the key word.

A long and depressing list of natural hazards and impacts resulting from climate change could be included here, however in this short essay it is neither possible nor relevant to be exhaustive in the description of the innumerable climate related social and economic problems which will emerge from climate change. We have pointed to the important precedents for improving the wellbeing of people through the kind of politics of social justice and intergenerational solidarity which gave us the welfare state and, for example universal health care. A similar approach could be taken towards current environmental degradation including climate change. While the debate continues in relation to the responsibilities which lie with the rich industrialised countries for the current and increasingly unsustainable state of the global environment, the urgency for articulating the governance of this problematic are evident. Any strategy has to incorporate sustainability or intergenerational solidarity and support socially just policies for tackling the accelerated environmental deterioration of the contemporary world.

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II. Environment and Technology

Development and Applications of Al-based Materials with High Specific Strength

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Abstract

This paper reviews the features of alloy components, structure and mechanical properties, physical and chemical properties of metastable Al-based alloys developed by use of various liquid or vapor quenching-induced phases such as amorphous, quasicrystalline, nanocrystalline, nanocomposite, supersaturated solid solution and structure gradient phases. As advantages of the metastable Al-based alloys, one can exemplify a high tensile strength of 1500 MPa for amorphous alloys, high elevated temperature strength of 364 MPa at 573 K for nanoquasicrystalline alloys, high strength of 1000 MPa at room temperature and 520 MPa at 473 K for nanocrystalline alloys, relatively high strength of 596 MPa with large elongation of 16 % for nanocomposite alloys and high strength of 900 MPa and distinct elongation of 5 % for supersaturated fcc-Al solid solution. These highly functional properties, which have not been obtained for conventional crystalline Al-based alloys, have enabled the commercialization of metastable Al-based alloys as structural, machinery and sporting goods materials. Owing to the significant increase of various fundamental properties caused by the essential differences in the structures, the engineering importance of the metastable Al-based alloys is expected to increase steadily in the future low carbon and nature harmonious society.

Keywords: Aluminium alloys, metastable phases, mechanical properties,

1. Background and Objectives

In recent years, there has been a strong demand of developing advanced structural materials with functional properties such as high specific strength, high elevated temperature specific strength, high fatigue specific strength, low corrosion loss and low wear loss. This is because the practical uses of these functional structure materials are expected to cause the saving of material amount, reductions of material cost and energy during material production as well as the saving of consuming energy during practical uses. Besides, the light-weight materials with high corrosion resistance and high wear resistance are effective for the increase of endurance limit and the lightening of final products. Thus, the development of novel Al-based alloys having simultaneously the above-described functional properties is particularly important nowadays.

As strengthening mechanisms for Al-based alloys, the following seven mechanisms are generally known [1]: solid solution, grain size refinement, work hardening, age hardening, precipitation, dispersion and defect-induced solute segregation. We have also noticed that the use of rapid quenching enables highly supercooled liquid solidification in conjunction with a high nucleation rate and low growth rate. By utilizing the high nucleation rate and low growth rate phenomenon, we have synthesized various kinds of metastable phases which change from nanocrystalline base structure to bulk glassy base structure through an amorphous base structure with increasing quenching effect (cooling rate). It is also known that the quenching effect is dominated by cooling rate from melt resulting from rapid solidification processes as well as by supercooling capacity of alloy liquid depending on alloy component and composition.

When we focus on the strengthening caused by metastable phases, the effect is due to the combination of solid solution + ultra-high density of defects for amorphous phase and dispersion + grain size refinement + segregation for nanocrystalline phase. The amorphous plus nanocrystalline mixed phase alloys are expected to have simultaneously almost all the strengthening mechanisms. By utilizing the combined strengthening mechanisms of these metastable phases, we have tried to prepare novel Al-based alloys with the high tensile strength exceeding 1500 MPa at room temperature, high elevated temperature strength above 500 MPa at 573 K, high rotating beam fatigue strength above 400 MPa at

10^7 cycles, high elevated temperature fatigue strength above 100 MPa at 673 K after 10^6 cycles and high corrosion resistance below 20 mm/year in 0.25 M NaOH aqueous solution at 293 K. In addition, these Al-based alloys have been requested to exhibit a low wear loss, low coefficient of thermal expansion and low material density etc. This paper presents the review of the development achievements of metastable Al-based alloys obtained in our group on the basis of the above-described backgrounds and objectives.

2. Al-based amorphous alloys

The first synthesis of ductile Al-based amorphous alloy was made in 1987 for Al-Ni-Si system by Inoue et al [2]. The amorphous alloys containing more than 70 at% of Al exhibit a good bending ductility and tensile fracture strength (σ_f) of about 440 MPa. Besides, the amorphous alloys show a unique feature of distinct double halo rings in their electron diffraction patterns, suggesting the phase separation of the glassy phase. Similar double halo rings and peaks have subsequently been found in many Al-based alloy systems such as Al-Ni-Ce, Al-Mn-Si and Al-Mn-Ge etc. [2, 3]. Such phase separation behavior has been interpreted to result from a significant difference in the heats of mixing between Al-TM (Ni, Mn) and Al-Si or Al-Ge [2, 3].

Since the discovery of Al-based amorphous alloys by rapid quenching [2], we have performed a systematic study on the development of Al-based amorphous alloys with the aim of producing novel engineering Al-based alloys with high specific strength. In 1988, we have reported that an amorphous phase is formed even in Al-Ln (Ln=lanthanide metal) binary system [4]. The crystallization temperature (T_x) increases with increasing Ln content and reaches about 505 K at 12 % Sm even for the binary amorphous alloys. The addition of the late transition metals (LTM) such as Fe, Co, Ni and Cu to Al-Ln binary alloys was found to be very effective in extending the composition range where an amorphous phase is formed, as exemplified in Fig. 1 [3]. The effectiveness is the largest for Ni and no distinct difference in the effectiveness among the other three LTM elements is recognized for Al-Ln (Y, La or Ce)-LTM systems. The T_x of these amorphous alloys increase almost linearly with increasing Ln content and reach about 750 K at 15% Ln content. The T_x level is the highest for LTM=Fe and Co, followed by Ni and then Cu. Besides, we can recognize a linear relationship between E and T_x , H_v or σ_f for

Al-Y-Ni amorphous alloys [5]. The highest tensile strength of Al-Y-Ni amorphous alloys reaches 1140 MPa [5]. Similar Al-based amorphous alloys with a good ductility were also found in Al-TM-RE (where TM = transition metals, RE = yttrium and rare earths) system by S. J. Poon et al. [6-8].

The additional effect of the fourth TM (TM=Transition Metal) element to Al-Y-Ni and Al-Ce-Ni amorphous alloys was examined by choosing Zr, V, Nb, Cr, Mn, Fe, Co, Ni or Cu as TM element [9]. The Co, Fe and Ni elements were found to be useful for further extension of amorphous phase region in $(Al_{0.85}Ni_{0.05}Y_{0.10})_{100-x}M_x$ and $(Al_{0.84}Ni_{0.10}Ce_{0.06})_{100-x}M_x$ alloys. The H_v increases significantly with increasing the M content and the highest H_v reaches about 500 for M=Mn or Ni, as shown in Fig. 2 [9]. The most favorable quaternary Al-based alloy with a good bending ductility was decided to be $Al_{85}Ni_{15}Y_8Co_2$ and the tensile strength, E and H_v of the amorphous alloy were 1250 MPa, 74 GPa and 350, respectively, as summarized in Table 1. In addition to Al-Ln-TM systems, the amorphous alloys with a good bending ductility were formed in Al-Ni-ETM (ETM=Zr, Hf, Nb) ternary alloys and their amorphous alloys also exhibited rather high tensile fracture strength reaching about 800 MPa [10, 11]. Fundamental properties such as electrical resistivity and Hall coefficient also show a distinct compositional dependence. For instance, there is a clear tendency for electrical resistivity at room temperature of $Al_{90-x}Y_{10}TM_x$ amorphous alloys to increase from 0.7 to 2.3 $\mu\Omega m$ with increasing TM content. Here it is important to note that the Al-Ln-LTM amorphous alloys exemplified for $Al_{85}Y_{10}Ni_{15}$ exhibit glass transition in the temperature range before crystallization. The glass transition can be recognized by the increase in specific heat, steep decreases in Young's modulus and tensile fracture strength, and drastic increase in elongation etc. Thus, Al-based amorphous alloys in the Al-Ln-LTM system can be classified as a glass type alloy. These glassy alloys have also been recognized to exhibit a much better corrosion resistance than those for pure Al and Al-Cu-Mg (2024) alloys in NaOH and HCl aqueous solutions at 298 K [12].

Subsequently, Inoue et al. have found that the addition of Sc to Al-Y-Ni-Co amorphous alloys is very effective for improvements of H_v and σ_f [13]. The H_v and σ_f increase almost linearly with increasing Sc content and reach about 450 and 1504 MPa, respectively, at 5%Sc, as shown in Fig. 3. The 5%Sc-containing glassy alloy exhibits a good bending ductility and can be bent through 180 degrees without

fracture. The tensile fracture takes place along the maximum shear stress plane and the fracture surface consists of well-developed smooth and vein patterns. Furthermore, a number of shear slip steps are observed in the region just near the fracture surface edge, indicating that the Al-Y-Ni-Co-Sc glassy alloy has a good ductile nature in spite of the high tensile strength exceeding 1500 MPa. It is also noticed that the specific tensile strength of σ/ρ for the glassy alloy exceeds 4.4×10^5 Nm/kg [13].

In addition to amorphous alloys in a ribbon form, Al-based amorphous alloy wires with a circular cross section have also been produced in the diameter range up to 100 μm by the melt extraction method. For instance, $\text{Al}_{85}\text{Ni}_{10}\text{Ce}_5$ amorphous alloy wire of 70 μm in diameter has a good bending ductility and can be bent through 180 degrees without fracture, as shown in Fig. 4. Besides, the wire exhibits high tensile fracture strength of 930 MPa [14].

Much effort has also been devoted to produce thick sheets of Al-based glassy alloys by developing an incremental quenching technique consisting of high pressure gas atomization, followed by incremental impact deposition on rotator. The thickness is in the range of about 0.12 to 7 mm and no crystalline phases are recognized in the X-ray diffraction patterns obtained from their sheets [15]. The formation of such thick sheets has been attributed to the incremental stacking of flattened powder. This is significant contrast to the small thickness (<1 mm) for Al-based alloys produced by conventional melting and casting.

If we can avoid the stacking of the powders which are flattened by the impact of spherical liquid droplets onto the rotator, there is a possibility of producing flaky powders which have not been obtained up date by the direct production method from liquid. Based on this concept, we developed a two-stage quenching technique in which the supercooled liquid droplets with very fast moving velocity produced by high pressure gas atomization can be flattened onto a rapidly rotating wheel [16]. The resulting Al-based flaky powders have very thin thickness of about 0.5 to 4 μm and large aspect ratios of 20 to 300 and exhibit very smooth outer surface with good metallic luster, as shown in Fig. 5. The two-stage quenching method also has an advantage of producing glassy alloy powders over the whole powder size range because all the spherical supercooled liquid droplets, which could not solidify to a glassy phase in the first solidification process of high

pressure argon gas atomization, are solidified to a glassy phase by the subsequent impact flattening, followed by deatching the flattened powder from the rotator by centrifugal force. We have also confirmed that the flaky Al-based glassy powder is suitable for application to a surface coating material because of its good metallic luster, thin thickness with large aspect ratio, high hardness, good bending ductility and high corrosion resistance [17, 18].

3. Bulk Glassy Alloys

It is important to obtain Al-based BMGs exhibiting high strength, good ductility and high corrosion resistance. By using the injection casting technique to copper mold, we produced glassy Al-based alloys in a sheet form with thickness up to 0.3 mm [19]. The increase in the thickness to 0.4 mm caused the coexistence of crystalline phase in the central region, though a glassy phase region is recognized in the edge region. We further tried to produce a thicker glassy alloy sheet by using a die-mold casting technique [20]. A nearly glassy phase was formed in the surface region of the sheets with a thickness up to about 3 mm, though the complete suppression of crystalline phase is difficult in the thick range of 0.5 to 3 mm. The production of the thick sheets with glassy surface coated layer seems to be important for future application as high specific strength, high surface hardness and high corrosion resistant materials in bulk form.

Very recently, Zhang et al. have reported that a mostly glassy alloy rod with a diameter of 1 mm is formed through the addition of 0.5 %Sc to Al-Ni-Y-Co base alloy by the copper mold casting method, though a tiny amount of fcc-Al phase is detected only in the central region of the rod [21]. The alloy rod exhibits a high compressive yield strength of about 1200 MPa and plastic strain of about 2.4 % in compression. A large number of shear bands can be observed on the lateral surface. With further increasing rod diameter to 1.5 mm and 2 mm, crystalline phases precipitate out in the central region of the rod and the yield strength decreases significantly in conjunction with the distinct change from ductile fracture surface mode for the 1 mm rod to brittle fracture mode for the 1.5 and 2 mm rods [21].

We further challenged to produce Al-based BMGs through the modification of alloy component for Al-Y-Ni-Co alloy. In the challenge, Domitri et al. have noticed that the 2 %Ca addition increases the reduced glass transition

temperature (T_g/T_f) value from ~ 0.55 at 0%Ca to 0.613 at 2 %Ca through the increase of T_g and the decrease of T_f [22]. Besides, the 2%Ca-containing amorphous alloy has been reported to have an activation energy for crystallization of about 311 kJ/mol which is much higher than those for other known Al-based glassy alloys. Based on the knowledge of the high T_g/T_f value and the difficulty of crystallization, we have tried to produce a bulk glassy alloy by the injection casting technique. However, we could not produce any bulk glassy alloy with a diameter of 1 mm because of the difficulty of suppressing the precipitation of Al₄Ca phase. The easy precipitation of Al₄Ca is presumably due to a much larger negative heat of mixing for Al-Ca pair as compared with those for other atomic pairs of Ca-Y, Ca-Ni and Ca-Co [21].

4. Al-based Nanocrystalline Alloys

When Al-rich Al-Ln-TM alloys containing about 88 at% are selected, their amorphous alloys crystallize through two exothermic peaks [23-25]. The first broad peak is due to the precipitation of nanoscale fcc-Al phase with a grain size of 3 to 10 nm. When the amorphous alloy is annealed in the first broad exothermic peak temperature range, the annealed alloy consists of nanoscale fcc-Al phase surrounded by the remaining amorphous phase. The precipitation of nanoscale fcc-Al phase causes significant increases of H_v , E and σ_f . For instance, as shown in Fig. 6, the Al₈₈Ni₉Ce₂Fe₁ nanocrystalline alloys exhibit the maximum σ_f of 1560 MPa at about 25 % volume fraction (V_f) of fcc-Al phase in conjunction with high H_v of 403 and E of 71 GPa [25]. The fracture surface of the nanocrystalline alloy ribbon shows a well-developed ledge pattern with much larger surface ruggedness, indicating a significant increase of ductility by the existence of nanoscale fcc-Al phase. The significant increase in tensile fracture strength is presumably because the nanoscale fcc-Al phase can act an effective resistance medium to shear sliding of the glassy phase. The nanocrystalline alloy also exhibits a high heat resistant strength of about 950 MPa even at 573 K as well as the improvement of ductility. There is a good linear relation for H_v to increase with increasing volume fraction of fcc-Al phase [25]. The relation agrees well with the result obtained by the simple mixture rule.

Here it is important to investigate the reason why the nanoscale fcc-Al phase can increase the tensile fracture strength of the nanocrystalline alloy. The

significant increase implies that the strength of nanoscale fcc-Al phase is much higher than that for the glassy matrix. The reason for such a high strength of the nanoscale Al phase has been thought to be due to the following two factors, i.e., (1) defect-free perfect crystal structure, and (2) highly defected crystal structure. The former mechanism was proposed about 20 years ago [26]. However, recent HRTEM data shown in Fig. 7 indicates the existence of an ultra-high density of dislocations inside fcc-Al phase and the density reaches as high as the order of 10^{24} m^{-3} [27]. The introduction of such a high density of dislocations in the nanoscale Al phase may be due to the generation of residual internal stress caused by the difference in thermal expansion of coefficient and the imperfect formation of fcc-Al crystal structures from icosahedral-like atomic configurations.

By use of a spray-forming technique, fully dense nanocrystalline plates of Al-Y-Ni-Co-Si-La alloys were produced in the disc plate with a diameter of 200 mm and a thickness up to 12 mm [28]. The plates have the nanocrystalline structure of glassy and fcc-Al phases in the middle region. The nanocrystalline plates have rather high H_v of about 420 and high E of about 80 GPa. These H_v and E values are independent of the position in the sheet [28].

By warm extrusion of atomized powders consisting of amorphous plus fcc-Al phases, we can obtain fully dense bulk nanocrystalline alloys consisting of fcc-Al phase with grain size of about 200 nm including homogeneously dispersed particles with sizes of 50 to 200 nm [29]. The extruded bulk nanocrystalline alloys exhibit a high yield strength of about 850 MPa, high tensile strength of about 1000 MPa as well as a rather high elevated temperature strength of 250 MPa at 573 K which are much superior to those for A7075 alloy, as shown in Fig. 8. The bulk nanocrystalline alloys also exhibit a rather high rotation beam fatigue strength of 330 MPa after 10^7 cycles. It is thus concluded that the nanocrystalline alloy has a higher fatigue strength and higher tensile strength than those for conventional Al-based alloys and newly developed Al-based alloys produced by powder metallurgy processes [1, 29]. The nanocrystalline alloys also have lower thermal expansion coefficient and lower wear losses than those for A6061, A5056 and A-17mass %Si alloys.

The nanocrystalline structure had rather high thermal stability and kept fine grain size of about 1 μm even after annealing for 30 min at 873 K [30]. The

rather high nanocrystalline structure stability has enabled the appearance of superplasticity with m value of 0.3 to 0.5 and elongation of about 500 %, indicating that the superplastic forming process can be applied to the bulk nanocrystalline alloys. In particular, bulk nanocrystalline Al-Ni-Mm-Zr alloy with grain size of 120 nm exhibits good combined properties, e.g., 830 MPa for the yield strength, 890 MPa for the tensile strength, 96 GPa for E and 4 to 9 % for elongation [31]. The yield strength obeys well the Hall-Petch relation which can be presented by $\sigma_{0.2} = 489 + 3.65d^{-1/2}$. This relation is significantly different from that ($\sigma_{0.2} = 5 + 2.30d^{-1/2}$) for conventional Al-based alloys [32]. The significant difference indicates that the strengthening mechanisms are significantly different between the bulk nanocrystalline and conventional Al-based alloys, in agreement with the phenomenon expected in the section of background.

5. Al-based Nanocomposite Alloys

For an Al-rich $\text{Al}_{95}\text{Zr}_1\text{Ni}_1\text{Mm}_3$ alloy, it has been found that the atomized powder of about 250 μm in diameter has a unique solidification structure in which a primary precipitation phase of Al_3Zr is surrounded by eutectic $\text{Al} + \text{Al}_{11}\text{Mm}_3$ phases, as exemplified in Fig. 9 [33]. The grain sizes of each constituent phase are much smaller than those for commercial powder metallurgy Al alloys such as SUMIALTOUGH and A390, in spite of much higher Al composition. The bulk nanocomposite Al-Zr-Ni-Mm alloy produced by warm extrusion of the atomized powders with the unique solidification structure keeps a high hardness above 84 in the temperature range up to 773 K and exhibits a rather high yield strength of about 530MPa at room temperature, 210 MPa at 573 K and 100 MPa at 673 K. In addition, the nanocomposite alloy exhibits a high elevated temperature fatigue strength of 190 MPa at 423 K and 160 MPa at 473 K after 10^6 cycles which are much superior to those for commercial AC8A-T7 alloy. It is noticed that the nanocomposite bulk alloy keeps high fatigue ratios of about 40 in a wide temperature range up to 673 K. The alloy also exhibits high impact fracture energy of 15 to 25 J/cm^2 [33]. It is thus said that the nanocomposite alloys of $\text{Al}_{95}\text{Zr}_1\text{Ni}_1\text{Mm}_3$ and $\text{Al}_{95}\text{Zr}_1\text{Mm}_4$ possess favorable combination of good static and dynamic mechanical properties and have been commercialized as heat resistant Al-based materials even at present.

6. Al-based Nano-quasicrystalline Alloys

It is known that the quasicrystalline phase has a number of advantages such as low growth rate, high resistance to elastic and plastic deformations, high heat-resistant strength, high wear resistance, low coefficient of thermal expansion, low thermal conductivity, isotropic properties, pseudo spherical morphology, Al-rich composition, isolated homogeneous dispersion surrounded by Al, dissolution of many solute elements and high corrosion resistance etc. [34-36]. By utilizing these advantages, we have been trying to develop a new type of Al-based alloy containing quasicrystalline phase as a main constituent phase [37]. For instance, the as-spun structure of $\text{Al}_{94}\text{V}_4\text{Fe}_2$ alloy changed from Al + amorphous to quasicrystalline (Q) phases through Al + amorphous + Q phases with decreasing cooling rate, as shown in Fig.10 [38]. The as-spun alloy ribbon exhibited the maximum tensile fracture strength of about 1400 MPa in the structure state of Al + Am + Q phases. The size was as small as 50 to 100 nm for the fcc-Al and 10 to 80 nm for the Q phase [38].

Such a mixed structure of fcc-Al + Q phases has been reported to be formed in as-atomized powders and as-extruded bulk forms from atomized powder for a number of Al-based alloys such as Al-Fe-Cr-M (M=Ti or V) [39], Al-Cr-Ce-M [40], Al-Mn-Cu-M [41] and Al-Cr-Cu-M [41] systems. The nano-Q bulk alloys can be classified to the following three types, (1) high-strength type of Al-Cr-Ce-Ti (or V) and Al-Mn-Ce alloys with tensile strength of 600 to 800 MPa and elongation of 5 to 10%, (2) high-ductility type of Al-Mn-Cu-Ti (or V) and Al-Cr-Cu-Ti (or V) alloys with a tensile strength of 500 to 600 MPa and elongation of 12 to 30 %, and (3) high-elevated temperature strength type of Al-Fe-Cr-Ti alloys with tensile strength of 350 MPa at 573 K [42].

Based on the above-mentioned basic knowledge that Al-Fe-Cr-Ti alloys have the high elevated temperature strength [43], much effort was devoted to develop a new type of heat resistant strength alloys with better performance in collaboration with Honda Research & Development Corporation [44] because there have been strong needs for high strength and heat resistant materials for automobile industries. We examined the additional effect of TM elements on the formation tendency of nano-Q structure in $(\text{Al-Fe-Cr-Ti})_{100-x}\text{Co}_x$ alloys. As a result, it has been clarified that the addition of 3 % Co causes the change to amorphous phase and the

2% Mo addition is effective for the refinement and homogenized dispersion of the Q phase. Therefore, we have decided that the most suitable alloy composition is $\text{Al}_{93}\text{Fe}_{2.45}\text{Cr}_{2.45}\text{Mo}_{0.5}\text{Ti}_{0.8}\text{Co}_{0.8}$. The extruded bulk alloy was produced in the following extrusion condition; (1) powder size was below 150 μm , (2) degassing was made for 3 h at 573 K in vacuum, (3) heating was made for 1 h at 673 K and (4) warm extrusion ratio at 673 K was 11. The Q particles in the extruded bulk alloy have a size of about 100 nm and about 75 % volume fraction. The extruded alloy exhibits a high tensile strength of 710 MPa at room temperature, 364 MPa at 573 K and 203 MPa at 673 K, all of which are much higher than those for A2618-TC. The alloy also exhibits high elevated temperature fatigue strength of 100 MPa at 623 K after 5×10^6 cycles under uniaxial tension-compression load. The nano-Q alloy also exhibits lower specific wear rate of 2.8×10^{-7} mm^2/kg at the sliding velocity of 2 m/s, higher E of 72 GPa at 673 K and lower thermal expansion coefficient of 22×10^{-6} K^{-1} at 673 K as compared with commercial A2618-T6 alloy.

The formability of the extruded alloy was also examined by compression test at a strain rate of 0.78 s^{-1} at 673 K. After 60 % compression strain, neither crack for the deformed alloy nor grain growth of Q phase was observed. The nano-Q alloy exhibits higher tensile strength values at room temperature and elevated temperatures of 473 to 673 K, higher wear resistance, higher Young's modulus and lower coefficient of thermal expansion in comparison with A2618-T6 alloy, though the elongation is lower and the density is higher. The newly developed nano-Q Al-Fe-Cr-Ti-Co-Mo alloy has been tested for applications to some heat-resistance parts in automobiles at present.

Here it is important to describe that the development of new Al-based alloys by use of the homogeneous dispersion of nanoscale quasicrystalline phase surrounded by the fcc-Al phase has been carried out at present in many countries [45-48] by the trigger effect of our data [34, 37-41].

7. Al-based Alloys Reinforced with Bulk Glassy Alloys

The reinforcement of Al crystalline alloys with bulk glassy alloys is expected to enable the production of novel Al-based alloys with features of inexpensive PM metallurgy process, high specific strength, good ductility and material weight reduction. We chose three kinds of bulk glassy alloys, i.e., $\text{Cu}_{54}\text{Zr}_{36}\text{Ti}_{10}$, $[(\text{Fe}_{0.5}\text{Co}_{0.5})_{0.75}\text{B}_{0.20}\text{Si}_{0.05}]_{96}\text{Nb}_4$ and $\text{Fe}_{72}\text{B}_{14.4}\text{Si}_{9.6}\text{Nb}_4$, because their T_g are

comparable to T_m of Al [49-51]. By sintering the mixture of Al powder and the FeCo-based glassy alloy powder at around T_g , fully dense composite alloys are produced and exhibit a rather high compressive yield strength of about 600 MPa in conjunction with large strain of about 12 % [51]. The yield strength level is comparable to weight reduction by about 60 %. The simple production method to produce the Al-based bulk alloy with high strength and high ductility is attractive for future development of new PM Al-based composite alloys.

8. Vapor-deposited Al-based Alloys

By using a two-target electron-beam evaporation equipment, vapor-deposited Al-based alloy sheets in a form of 120×120×1 mm were formed in Al-TM (TM=Fe, Zr, Ni, Ti, Cr) systems [52-54]. For instance, the Al-Fe deposited sheets consist of fcc-Al solid solution saturated with Fe and the fcc-Al phase has a grain size of about 2 μm at about 1 %Fe, about 200 nm at 1.3%Fe and about 20 to 40 nm at 2.6 and 3 at% Fe [52]. Thus, the grain size decreases drastically in the vicinity of 1.5 to 2 at% Fe. The 0.9 to 2.2 % Fe alloy sheets exhibit high H_v of about 220 to 260, high yield strength of 700 to 900 MPa and elongation of 5 to 9 %, as shown in Fig. 11. The highest tensile strength attained was about 1000 MPa at 2.6% Fe and the H_v of the 2.6% Fe alloy sheet was about 300. In addition to the high tensile strength, the Al-Fe alloy sheets with 0.9 to 1.2 % Fe exhibited high fracture toughness of 65 to 75 MPa m^{1/2}. The best combined properties of tensile strength and fracture toughness were 860 MPa and 75 MPa m^{1/2}, respectively, for the Al-0.9%Fe alloy sheet. Both hardness and tensile strength are proportional to the reciprocal square root of the grain size, as shown in Fig. 12. The Al-Fe alloy sheets also show a good Hall-Petch relation even in the high tensile fracture strength level of 700 to 1000 MPa.

The local structure around Fe atom in the vapor-deposited Al-Fe sheets was also examined by the Fe K-absorption edge EXAFS method [55]. The first neighbor atomic distance of the Al-2%Fe alloy sheet agrees well with those for Al₃Fe and Al₂Fe compounds and deviates significantly from that of the fcc-Al phase, indicating the development of Al-Fe short range ordered atomic configurations which can play an important role in the achievement of an ultra-high tensile strength for the Al-Fe deposited sheets.

Similar high strength nanocrystalline alloy sheets were also produced for Al-Zr and Al-Fe-Zr sheets [53]. For instance, the $\text{Al}_{95.3}\text{Zr}_{4.0}\text{Fe}_{0.07}$ alloy sheet of 1 mm in thickness consists of fcc-Al supersaturated solid solution with fine grain sizes of 260 to 680 nm and exhibits a high elevated temperature strength of 800 MPa at room temperature, 536 MPa at 523 K and 434 MPa at 573 K, all of which are much higher than those for 7075-T6 (ESD) alloy. It is thus concluded that the Al-Fe sheet is a high strength and high fracture toughness type, while the Al-Fe-Zr sheet is a high elevated temperature strength type material.

9. Structure Gradient Al-based Alloys

By sputtering $\text{Al}_{80}\text{Ti}_{20}$ and $\text{Al}_{80}\text{Zr}_{20}$ in a mixed gas atmosphere of Ar + N_2 , the structure-gradient Al-based alloy films have been produced [56-58]. For instance, the structure of the Al-Ti alloy films produced by controlling nitrogen partial pressure changes from an fcc-Al supersaturated solid solution to AlN through amorphous, and amorphous + AlN phases with increasing partial nitrogen pressure from 0 to 0.12 [57]. The structural change caused a significant change of Knoop hardness from 325 for Al-phase to 2310 for AlN through 430 to 910 for the amorphous phase, as shown in Fig. 13. The amorphous phase had a wide range of Knoop hardness values ranging from 429 to 900 with increasing partial nitrogen pressure from 0.02 to 0.07. Similar changes in the structure and Knoop hardness have also been obtained for $(\text{Al}_{0.8}\text{Zr}_{0.2})_{100-x}\text{N}_x$ alloy films [58].

10. Applications

Bulk nanocrystalline Al-based alloys in Al-Ni-Mn-Zr system with a trademark of GIGAS were commercialized as machinery, structure and sporting goods parts by YKK Corporation [42]. The real application fields were robot parts such as arm, finger and foot, machinery parts, die cast molds, sporting goods such as soft baseball bat, tennis racket and golf club etc., light weight tools, fishing reel, gear in bicycle and wheelchair parts, as exemplified in Fig. 14. The achievement of application is due to the simultaneous satisfaction of the high specific strength, high specific modulus, high fatigue limit, low coefficient of thermal expansion, low wear resistance and high corrosion resistance.

The nanocomposite Al-based alloys in the Al-Ni-Mm-Zr system with a trademark of NANOALUMI have also been commercialized as high heat resistant and toughness materials even at present by Sumitomo Electrical Corporation [59].

11. Conclusions

We have developed metastable Al-based alloys consisting of amorphous, nanocrystalline and nanoquasicrystalline phases. These new metastable Al-based alloys exhibit high static and dynamic mechanical properties, high elevated temperature strength and good workability which have not been obtained for conventional Al-based crystalline alloys. It is expected that bulk metastable alloys with more functional characteristics and larger material dimensions will be obtained through the fabrication of new structures via novel alloy compositions and production processes. By more effective use of metastable phases, there is a high possibility of commercializing new metastable materials such as higher heat resistant nano-quasicrystalline materials, surface-coated Al-based glassy materials, vapor-deposited Al-based nanocrystalline materials and structure and/or composition gradient materials. It is believed that the further developments of these novel Al-based metastable alloys will contribute greatly to the future sustainable society.

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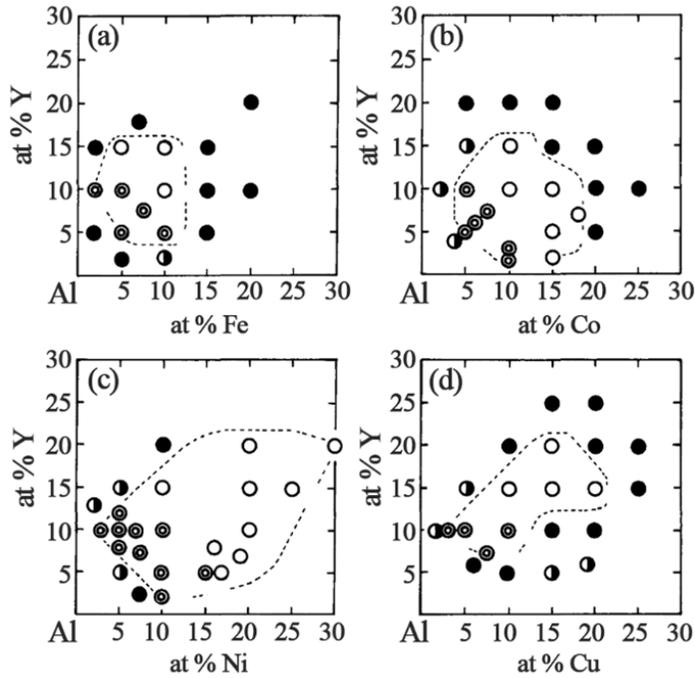


Fig. 1 Compositional range for formation of amorphous phase in (a) Al-Y-Fe, (b) Al-Y-Co, (c) Al-Y-Ni and (d) Al-Y-Cu systems: (⊙) amorphous (ductile); (○) amorphous (brittle); (◐) amorphous plus crystalline; (●) crystalline [3].

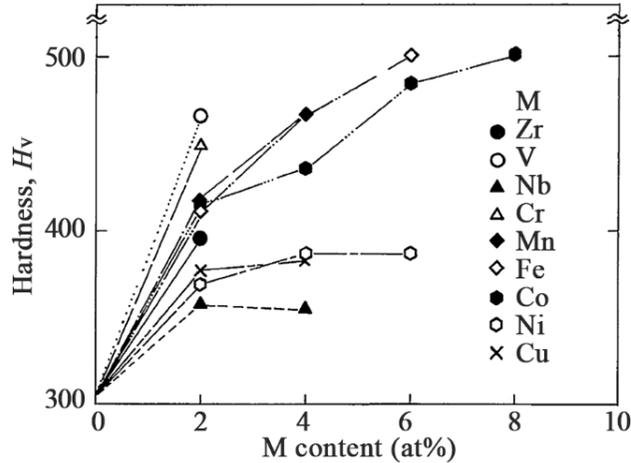


Fig. 2 Changes in Vickers hardness (H_v) of $(Al_{0.85}Ni_{0.05}Y_{0.10})_{100-x}M_x$ ($M=Zr, V, Nb, Cr, Mn, Fe, Co, Ni$ or Cu) amorphous alloys with an increase of the M content [9].

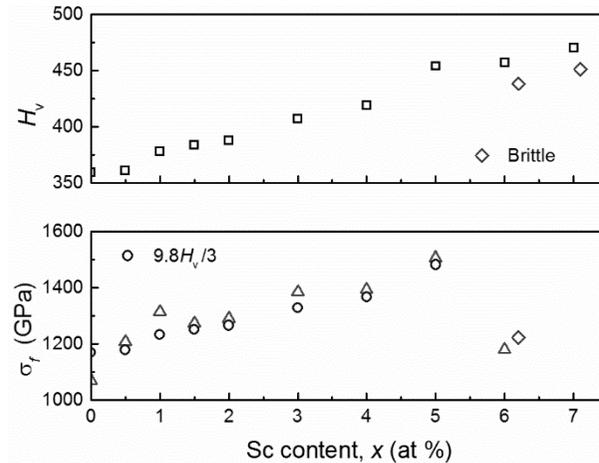


Fig. 3 Vickers hardness and tensile strength values as a function of Sc content in $(\text{Al}_{0.64}\text{Y}_{0.09}\text{Ni}_{0.05}\text{Co}_{0.02})_{100-x}\text{Sc}_x$ amorphous alloys [13].

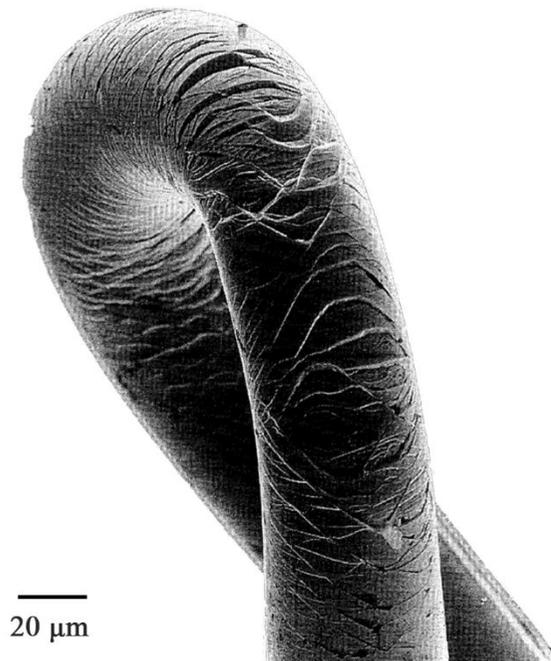


Fig. 4 Scanning electron micrograph revealing the deformed structure of an $\text{Al}_{85}\text{Ni}_{10}\text{Ce}_5$ wire which was bent through 180 degrees [14].

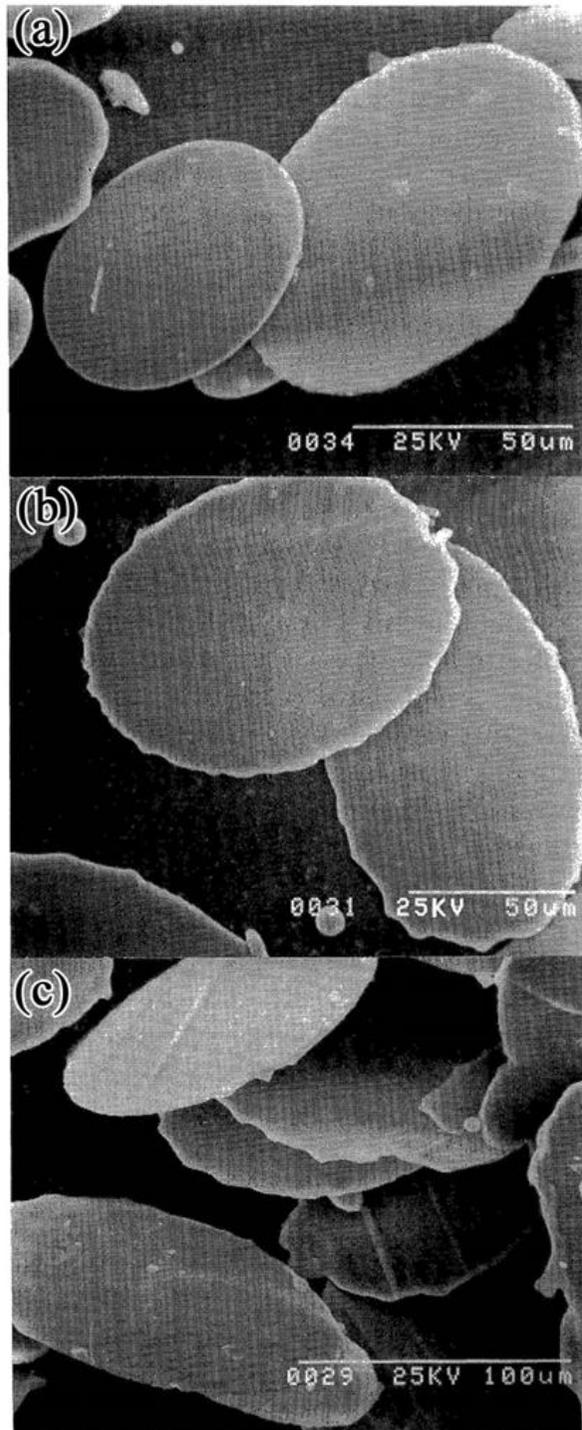


Fig. 5 Scanning electron micrographs revealing effect of size fraction on morphology in $\text{Al}_{85}\text{Ni}_{7.5}\text{Mm}_{7.5}$ powder produced by the two-stage quenching method. (a) 25 to 45 μm , (b) 45 to 63 μm , (c) 63 to 75 μm [16].

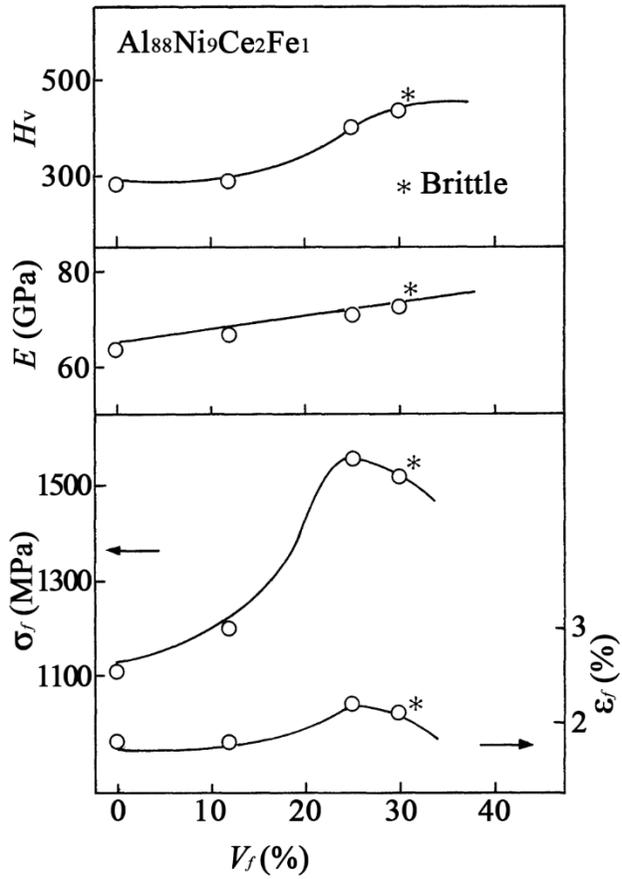


Fig. 6 Hardness (H_v), Young's modulus (E), tensile fracture strength (σ_f) and fracture elongation (ϵ_f) as a function of V_f for melt-spun Al₈₈Ni₉Ce₂Fe₁ amorphous alloys [25].

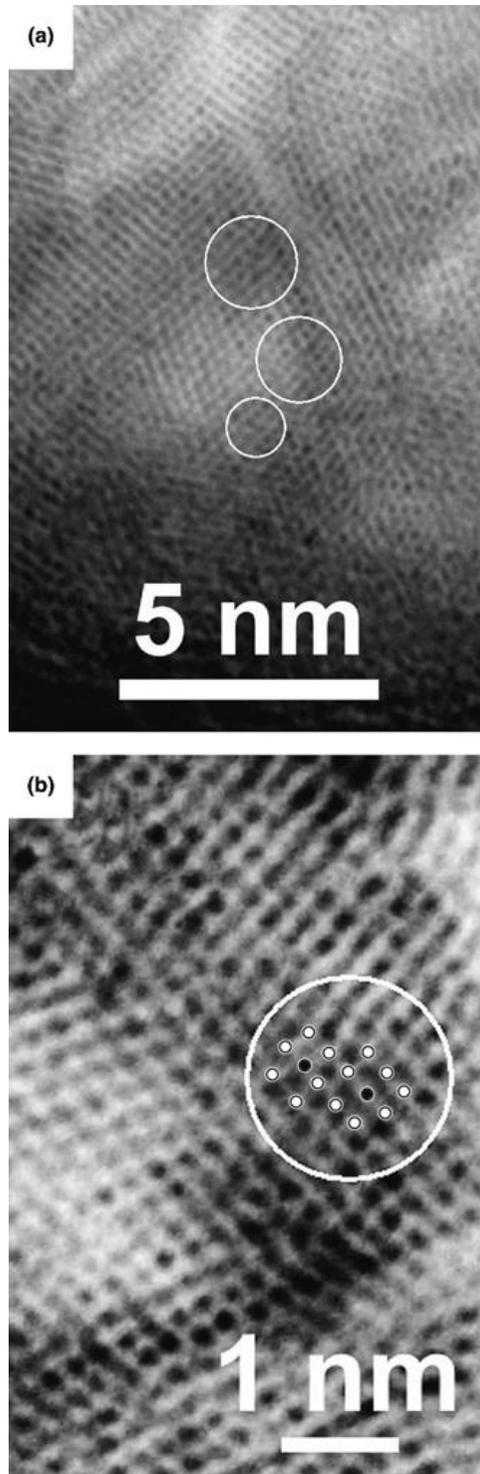


Fig. 7 High-resolution TEM images of the $\text{Al}_{85}\text{Y}_4\text{Ni}_5\text{Co}_2\text{Pd}_4$ glassy alloy in as-solidified state [27].

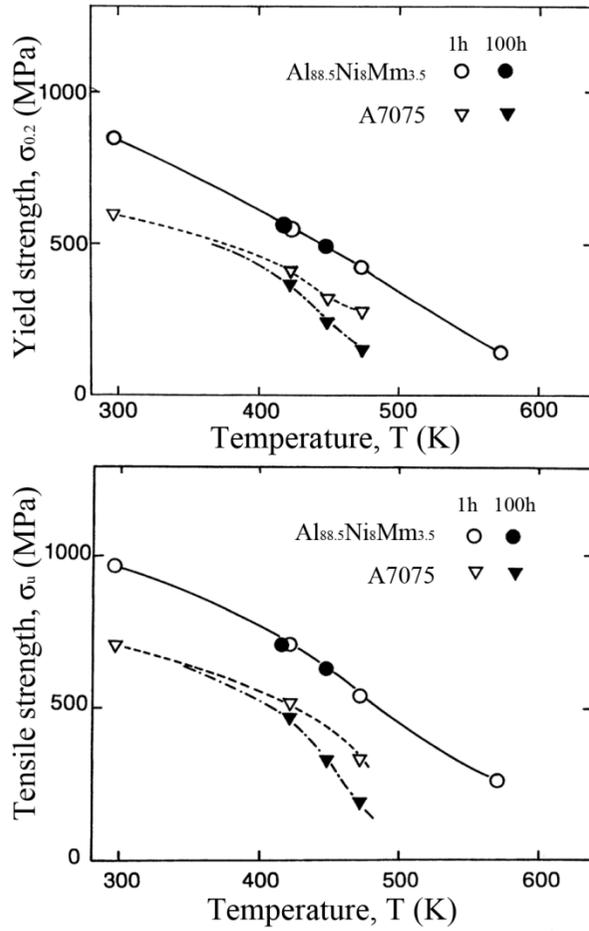


Fig. 8 Temperature dependence of tensile yield strength ($\sigma_{0.2}$) and ultimate tensile strength (σ_u) for as-extruded Al_{88.5}Ni₈Mm_{3.5} alloy annealed for 1 and 100 h at each testing temperature. The data for the A7075 allow are also shown for comparison [29].

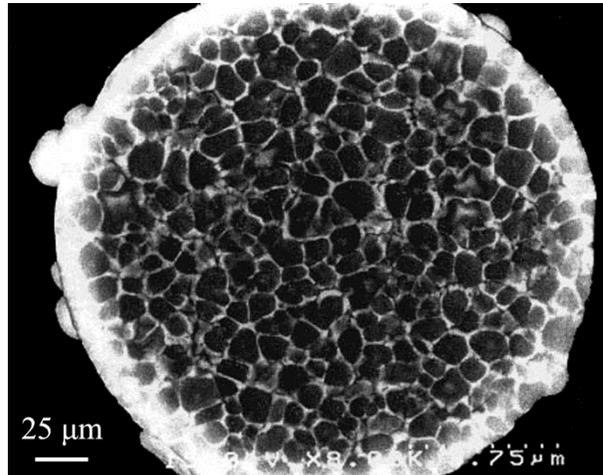


Fig. 9 Scanning electron micrograph of atomized $\text{Al}_{95}\text{Zr}_1\text{Ni}_1\text{Mm}_3$ alloy powder [33].

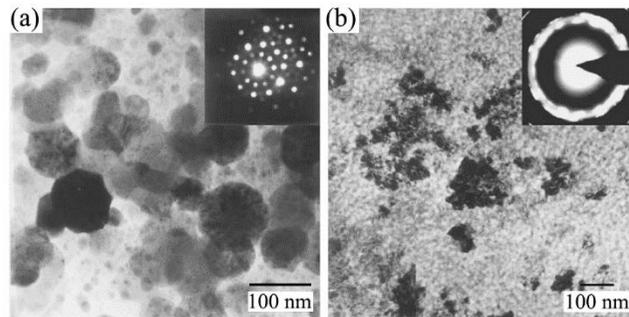


Fig. 10 Bright field TEM images of $\text{Al}_{94}\text{V}_4\text{Fe}_2$ alloy melt-spun at (a) 20 and (b) 50 m/s. The inset of (a) is the microdiffraction pattern obtained from an i-phase particle and that of (b) is the selected area diffraction pattern from the alloy melt-spun at 50 m/s [38].

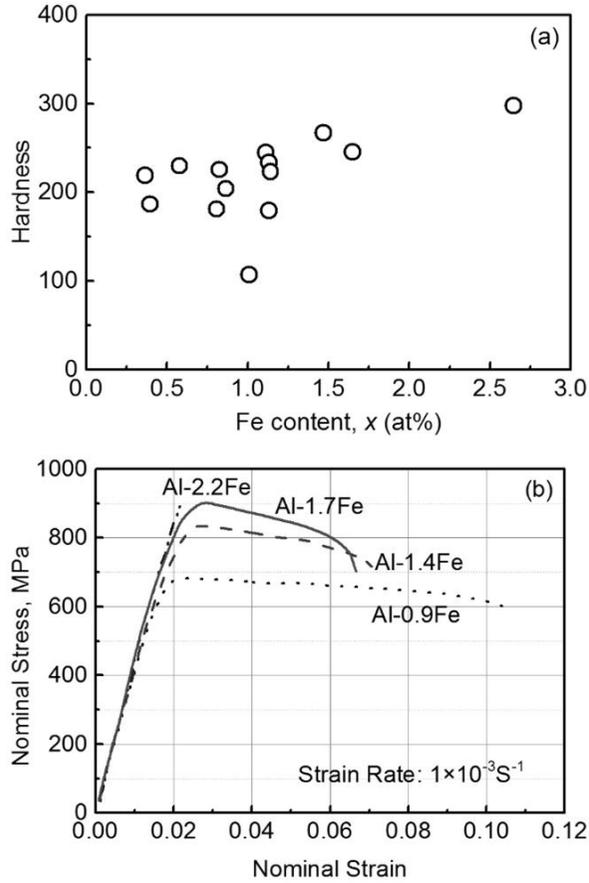


Fig. 11 Relationship between (a) Fe content and Vickers hardness and (b) Stress-Strain curve of Al-Fe deposited alloy [52].

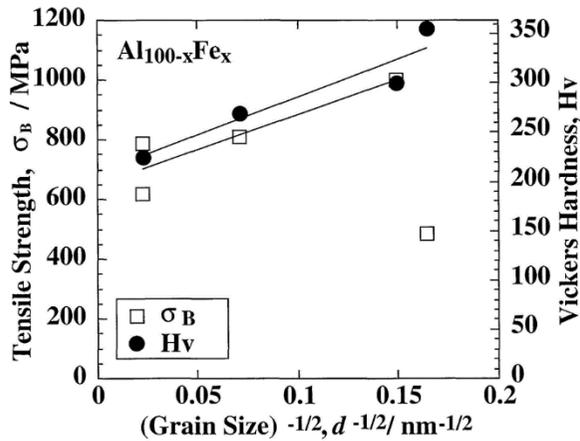


Fig. 12 Grain size dependence of tensile strength and Vickers hardness of Al-Fe deposited alloy [52].

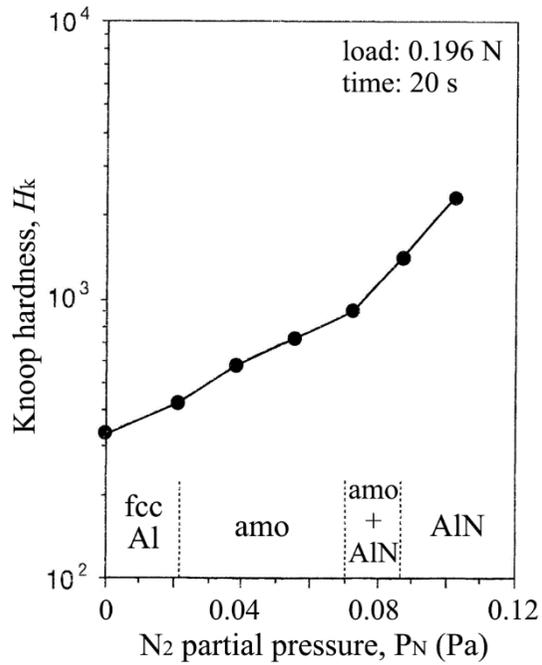


Fig. 13 Knoop hardness number (H_K) as a function of P_N for the fcc-Al(Ti), amorphous Al(Ti, N), amorphous plus hexagonal Al(Ti)N and hexagonal films [57].

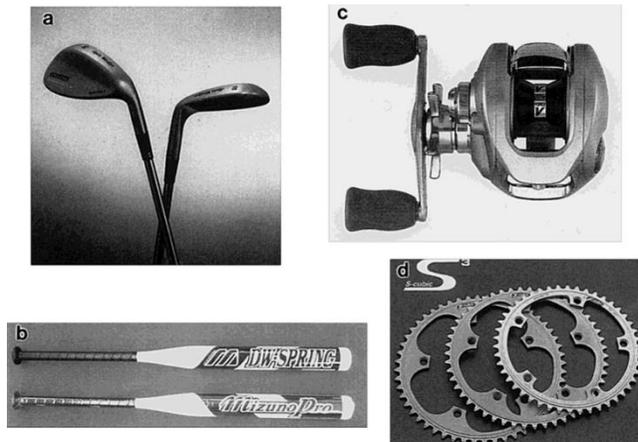


Fig. 14 Application examples of nanocrystalline Al-based alloys: sporting goods (a, b), fishing reel (c) and gears in bicycle (d). These data were taken from YKK and Daiwa Corporations [42].

Table I Mechanical properties of Al-Ni-Y and Al-Ni-Y-Co amorphous alloys [9].

Alloys	σ_f (GPa)	E (GPa)	H_v	ε_t (%)	$\varepsilon_{c,y}$	$\sigma_{c,y}$ (MPa)
Al ₈₅ Ni ₅ Y ₁₀	920	62.8	310	1.4	0.016	1010
Al ₈₅ Ni ₅ Y ₈ Co ₂	1250	74.0	350	1.7	0.015	1145
Al ₈₅ Ni ₅ Y ₇ Co ₃	1140	71.2	340	1.5	0.016	1110

Tensile fracture strength (σ_f), Young's modulus (E), Vickers hardness (H_v), tensile fracture strain (ε_t), compressive yield strain ($\varepsilon_{c,y} \approx 9.8H_v/3E$) and compressive yield strength ($\sigma_{c,y} \approx 9.8H_v/3$).

Bulk Metallic Glasses: as Environmental Advanced Materials¹

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Introduction

For the past two decades, bulk glassy alloys with unique characteristics were developed in engineering important transition metal base systems such as Zr-, Ti-, Fe-, Co-, Ni-, and Cu-based alloys. The maximum diameter for glass formation reaches 32 mm for Zr-based systems, 10 mm for Ti-based systems, 18 mm for Fe–Co-based systems, 20 mm for Ni-based systems, and 25 mm for Cu-based systems when using copper mold casting techniques. These large-size bulk glassy alloys possess nearly the same fundamental properties as those for the corresponding glassy alloys with diameters <5 mm. In addition to some previously developed systems such as sporting goods, casing and optical parts, application stages of bulk glassy alloys in Fe-, Co-, Ti-, and Zr-based alloys have advanced significantly in functional systems, such as choke coils, power inductors, electromagnetic shielding, micro-gearred motors, pressure sensors, Colliori-type mass flow meters, high corrosion-resistant surface coating layers, precise surface polishing materials, medical instruments, and so forth. This article reviews recent advances in the formation and applications of bulk glassy alloys as engineering materials.

Key words: Amorphous and Nanocrystalline Materials; Glass Transition; Metallic Glasses.

1. History of Bulk Glassy Alloys

Since 1990, the thermal stability of supercooled liquids against the crystallization of metallic alloys has increased significantly and the resulting lowest critical

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cooling rate for glass formation reaches values as low as 0.033 K/s which is 10^8 and 10^9 times smaller than those of ordinary amorphous alloys and conventional crystalline alloys (Inoue 1995, 2000, 2001, Johnson 1999). Such a dramatic increase in the thermal stability of supercooled liquids has enabled us to fabricate bulk glassy alloys with various outer shapes, for example, a massy alloy ingot of 72 mm in diameter and 85 mm in height, a cylindrical rod of 25 mm in diameter and 300 mm in length and hollow pipes of 10 mm in outer diameter, 1 mm in thickness, and 1.5 m in length for Zr-, Pd-, and La-based alloy systems (Inoue 2000). In addition, glassy alloy sheets with uniform thickness and large specific surface ratios as well as glassy alloy balls with diameters of over 10 mm are available at present for Zr-based alloy systems (Inoue et al. 2008). Recently, the critical diameter has reached values of more than several centimeters even for Zr- (Inoue and Zhang 1996), Ni- (Zeng et al. 2006), and Zr–Cu- (Zhang and Inoue 2004) based alloy systems as well as for Pd- (Inoue et al. 1996) based alloy system. Based on these recent significant developments of bulk glassy alloys, one can utilize new bulk metallic alloys consisting of a glassy structure in addition to conventional crystalline bulk metallic alloys which have been used for the past several thousands years.

2. Bulk Glassy Alloy Systems and Their Feature

Table 1 summarizes typical bulk glassy alloy systems reported to date together with the year when the first paper or patent for each alloy system was published. The alloy systems can be classified as nonferrous and ferrous alloy groups. Considering that the lanthanides (Ln) consist of at least 15 elements, the total number of bulk glassy alloy systems exceeds largely 500 types. The years between 1988 and 1993 can be regarded as an incubation period of bulk glassy alloy research. Based on the experimental results of bulk glassy alloy systems obtained in the latter period, Inoue (1995, 2000) proposed important features that alloy components should have for the stabilization of supercooled liquids and high glass-forming ability. These features consist of the following three factors: (i) multicomponent consisting of more than three elements, (ii) significant atomic size mismatch above 12% among the three main constituent elements, and (iii) negative heats of mixing among the three main elements. Since the mid-1990s, the

use of the three component rules has resulted in the development of a variety of bulk glassy alloy systems summarized in Table 1.

3. Features in Glassy Structure

For several years before 2002, it was also reported (Inoue 2000) that the alloys with the three-component rules have new glassy and liquidus structures with the following features: (i) a high degree of dense-packed atomic configurations, (ii) new local atomic configurations which are completely different from those for the corresponding crystalline phases, and (iii) long-range homogeneity with attractive interaction. Looking into more details of their structural features, metal-metal-type glassy alloys as exemplified by Zr-Al-Ni-Cu system are composed of icosahedral-like ordered atomic configurations. Pdmetalloid-type glassy alloys such as Pd-Cu-Ni-P system consist of highly dense-packed configurations of two types of polyhedrons of Pd-Cu-P and Pd-Ni-P atomic pairs, while metal-metalloid-type glassy alloys of Fe-(Zr,Hf,Nb)-B ternary systems have network-like atomic configurations in which distorted trigonal prisms of Fe and B are connected with each other in edge- and face-shared configuration modes through 'glue' atoms of Ln and the early transition metals Zr, Hf, or Nb. These icosahedral- and network-like ordered atomic configurations can suppress effectively the long-range rearrangements of the constituent elements which are necessary for the progress of the crystallization reaction. Consequently, one can obtain stabilized supercooled liquids leading to the formation of bulk glassy alloys even by various slow cooling processes. Very recently, several groups have reported more detailed structural results for bulk glassy alloys as exemplified by topological models based on coordination polyhedrons corresponding to the development of medium range order (Miracle 2004, Shen et al. 2006, Yavari 2006). Takeuchi et al. (2008) also proposed a new structure model by using molecular dynamics based on plastic crystal model. This model tries to construct the glassy structure through the sequential procedures of ensemble of clusters and glue atoms, followed by random rotations of clusters and then annealing-induced structural relaxation. The resulting atomic configurations can reconstruct the features of the total pair distribution function for bulk glassy alloys. These structure models suggest that the development of ordered atomic configurations on a medium-range scale plays

an important role in the stabilization of supercooled liquid for special multicomponent alloy systems which satisfy the three-component rules.

4. Engineering Bulk Glassy Alloys

4.1 Nonferrous Metal Base System

Based on the fundamental knowledge obtained for the past two decades, one can produce bulk glassy alloys with critical diameters of over 20mm for a variety of alloy systems such as those based on Pd, Zr, Ni, Cu, Mg, and Ln. The success of formation of such large-scale bulk glassy alloys has opened new engineering material and science fields. As application fields that have proceeded at present for bulk glassy alloys in Japan, one can mention structural materials, sensors, springs, sporting goods, wear-resistant and corrosion-resistant coatings, and magnetic alloys. Other fields involve micro- or nanotechnology, information storage, biomedical devices, and fuel cell separator materials. Here it is also important to point out that these materials have been developed in conjunction with the unique advantages of near net-shape and net-shape casting techniques and viscous flow formability. Focusing on engineering bulk glassy alloys, in practical uses they are limited to six alloy systems: (i) four host metal base types of Zr–Al–Ni–Cu, Fe–Cr–metalloid, Fe–Nb–metalloid, and Fe–Ni–Cr–Mometalloid systems and (ii) two pseudo-host metal base types of Zr–Be–Ni–Cu–Ti and Ti–Zr–Cu–Ni–Sn systems. Thus, one can notice that Zr- and Fe-based bulk glassy alloy systems are the most important materials for practical uses. Table 2 summarizes fundamental data of some standardized bulk glassy alloys which have been delivered at present by our group. It is recognized that Zr-based bulk glassy alloys in Zr–Al–Ni–Cu and Zr–Cu–Al–Ag systems exhibit highly reliable results on thermal stability as well as static and dynamic mechanical properties in the wide diameter range of over 10 mm. The three types of bulk glassy alloys in Zr–Al–Ni–Cu, Zr–Be–Ti–Cu–Ni, and Zr–Cu–Al–Ag systems were developed as typical Zr-based alloy systems by Zhang et al. (1991), Peker and Johnson (1993), and Zhang and Inoue (2004), respectively. Their maximum diameters are 32mm (Yokoyama et al., 2009b) for the Zr–Al–Ni–Cu system, over 30mm (Johnson 1996) for the Zr–Be–Ti–Cu–Ni system, and 25mm (Zhang et al. 2008b) for the Zr–Cu–Al–Ag system. Their Zr contents for bulk glass formation are in the range of 50–70 at.%, 42–44 at.%, and 42–48 at.%,

respectively. Only Zr–Al–Ni–Cu glassy alloys can contain high Zr contents ranging from 50 at.% to 70 at.% and can be regarded as a true Zr-based alloy system, while the Zr contents in the other two glassy alloys are less than 50 at.%. Consequently, it is more appropriate for the other two glassy alloys to be named as Zr–Be and Zr–Cu base alloy systems. Considering the experimental result that a eutectic alloy composition in Zr–Al–Ni–Cu quaternary system is located around $Zr_{55}Al_{10}Ni_5Cu_{30}$ (Yokoyama et al., 2007), the Zr–Al–Ni–Cu glassy alloys are extended over a wide composition range, including eutectic and hypoeutectic compositions. On the other hand, the other two Zr-based bulk glassy alloys appear to be located in the vicinity of the eutectic composition and can be regarded as a eutectic-type glassy alloy.

It has further been characterized that the hypoeutectic-type Zr–Al–Ni–Cu glassy alloys exhibit much better dynamic mechanical properties (Yoshida et al. 2007). Figure 1 shows the compositional dependence of Poisson's ratio of Zr–Al–Ni–Cu bulk glassy alloys. In the Zr concentration range from 50 at.% to 70 at.% for Zr–Al–Ni–Cu system, there is a distinct tendency for Poisson's ratio to increase with increasing Zr content and the 70% Zr-containing hypoeutectic alloy has a high Poisson's ratio of 0.387. The 70% Zr glassy alloy exhibited large plastic strain exceeding 40% under a uniaxial compression and did not show final rupture. A high density of shear bands can be observed on the peripheral surface of the severely deformed alloy rod. Even for the Zr-rich alloys subjected to the severe plastic deformation, one could not see any trace of deformation-induced nanocrystallization in the transmission electron microscopic images. In addition, the 70% Zr hypoeutectic alloy exhibits distinct plastic elongation of 1.7% under a uniaxial tensile deformation mode at a strain rate of $1.6 \times 10^{-1} \text{ s}^{-1}$. With further increasing strain rate to $5 \times 10^{-1} \text{ s}^{-1}$, the tensile plastic elongation increases further to 4.4%, as exemplified in Fig. 2 (Yokoyama et al. 2009a). The tensile plastic elongation is believed to be the largest for monolithic bulk glassy alloys without any deformation-induced nanocrystallization phenomenon. The tensile fracture occurred through the sequential processes of distinct necking, followed by shear sliding along the maximum shear stress plane and then final catastrophic rupture. The glass-forming ability of the hypoeutectic glassy alloys in the Zr–Al–Ni–Cu system was examined in comparison with the eutectic-type glassy alloy. The eutectic $Zr_{55}Al_{10}Ni_5Cu_{30}$ alloy rods can keep a glassy phase in the diameter range

up to 30mm (Inoue and Zhang 1996, Yokoyama et al. 2007) in the case of copper mold suction casting and 32mm by use of copper mold cap casting (Yokoyama et al. 2009b). Similarly, the maximum diameter for the hypoeutectic-type glassy alloys has been reported to be at least 20mm for $Zr_{60}Al_{10}Ni_{10}Cu_{20}$, $Zr_{61}Ti_2Nb_2Al_{7.5}Ni_{10}Cu_{17.5}$, $Zr_{60}Ti_2Nb_2Al_{7.5}Ni_{10}Cu_{18.5}$, and $Cu_{34}Zr_{48}Al_8Ag_8Pd_2$ (Inoue et al. 2009, Zhang et al. 2008b) and 16 mm for $Zr_{65}Al_{7.5}Ni_{10}Cu_{17.5}$ (Zhang et al. 2008a) by copper mold tilt casting. The thermal stability parameters T_g , T_x , and $\Delta T_x (=T_x - T_g)$, the static mechanical properties comprising Young's modulus, yield strength and plastic strain, and the deformation and fracture behaviors (via shear sliding along the maximum shear stress plane and then catastrophic final rupture) have been confirmed to be independent of picking position and angle to the longitudinal direction of the cast alloy rod as well as of the rod dimension in the diameter range up to 20 mm.

4.2 Ferrous Metal Base System

Since the first synthesis of Fe-based bulk glassy alloys in Fe–Al–Ga–P–C–B system (Inoue et al. 1995), a variety of Fe-based bulk glassy alloys have been developed. Table 3 summarizes the alloy systems of Fe-based bulk glassy alloys developed to date. Their alloy systems can be classified to ferromagnetic and nonferromagnetic types at room temperature. As recognized from Table 3, some Fe-based bulk glassy alloys have already been commercialized under the commercial names Licalloy (Mizushima et al. 2007) and SENNTIX (Matsumoto et al. 2007) for the former type and AMO-beads (Inoue et al. 2003) for the latter type. The Licalloy and SENNTIX soft magnetic alloys have unique combination of lower coercivity and higher electrical resistivity which have not been obtained for conventional Fe-based amorphous alloy cores and nanocrystalline Fe-based soft magnetic alloy cores. Such a low coercivity characteristic has been interpreted to originate from the formation of more homogeneous atomic configuration in the glassy state. These Fe-based bulk glassy alloys exhibit high fracture strength of 3000– 4000MPa and large elastic strain of about 0.02, which are significantly different from those for conventional Fe-based crystalline alloys. The SENNTIX-type bulk glassy alloy also exhibits high fatigue stress amplitude of about 2300 MPa after 10^7 cycles which is much superior to those for conventional Fe-based crystalline alloys (Fujita et al. to be submitted).

5. Applications

5.1 Zr- and Ti-based Alloys

Zr–Al–Ni–Cu glassy alloy diaphragms produced by net-shape casting have been applied to pressure sensors with unique features such as smaller size, higher sensitivity, and higher-pressure endurance which cannot be achieved for conventional stainless steel diaphragms (Nishiyama et al. 2007). Microgeared motor parts made of Zr–Al–Ni–Cu glassy alloy have also been produced by net-shape casting technique. By using these parts, the world's smallest geared motor with a diameter of 1.5mm and a length of 9.9mm has been produced and launched at present (Inoue 2007). The three-stage micro-geared motor has high torque which is about 20 times stronger than that for a conventional vibration motor with a diameter of 4mm used in ordinary cell phones. Besides, various types of connection adapters of curved sections and circularly piping have been produced by the net-shape casting technique. Consequently, the micro-geared motors in conjunction with the development of various types of connection adapters have been tested for applications to advanced medical equipments, including endoscope and micro-pump, precision optics, and micro-machines.

Ti-based glassy alloy pipes of 2mm in outer diameter, 0.2mm in thickness, and 300mm in length produced by net-shape casting technique exhibit high tensile strength and a large elastic strain of 0.02 which are suitable for application as sensing element in a Coriolis flow meter to measure mass flow of liquid or gas inside the pipe. The sensitivity of the Coriolis flow meter using the Ti-based glassy alloy pipe was reported to be 28–53 times higher than that for conventional SUS316 pipe (Ma et al. 2005). The significant improvement of sensitivity allows us to expect that the new type Coriolis flow meter is used in various industries such as chemical, environmental, semiconductor, and medical science fields.

5.2 Fe-based Glassy Alloys

The soft magnetic Fe-based glassy alloys in the Fe–Cr–P–C–B–Si system have been commercialized as Licalloy (Mizushima et al. 2007). The Licalloy magnetic cores have been produced by mass production using cold consolidation processes of atomized glassy alloy powders. The Licalloy cores exhibit nearly constant relative permeability in a wide frequency range up to several megahertz, good linear

relation between permeability and DC bias field, much smaller reduction in permeability in a wide DC bias field, and much lower core losses than those for Ni-Fe-Mo Permalloy and Fe-Si-Al Sendust cores. These excellent characteristics are partly attributed to the reduction in eddy current loss resulting from much higher electrical resistivity than those for Permalloy and Sendust cores. When the Licalloy core characteristics are compared with Mn-Zn ferrite core with much higher electrical resistivity, the Mn-Zn ferrite core exhibits nearly the same low core losses as that for Licalloy, but the Mn-Zn ferrite core shows significant reduction in permeability in the low current range and does not have a good linear relationship of permeability as a function of DC bias field in a wide current range. It is thus concluded that the Fe-based glassy alloy (Licalloy) cores have better soft magnetic characteristics than those for the other soft magnetic cores. The resulting Licalloy powder cores have been used as a power inductor in laptop-type personal computers because of higher efficiency and much smaller heat generation.

The Licalloy powder produced by water atomization can be deformed into flaky shape with a thickness of 2–3 mm and large aspect ratios of 10–30 which enables us to produce the sheet-form materials. The Licalloy sheet consisting of the flaky powder embedded in resin exhibits high convert ratio from electromagnetic noise to heat, leading to highly efficient suppression of noise. Therefore, the Licalloy sheet has been used as a noise suppression sheet in digital still cameras. Very recently, the Licalloy sheet has also been applied to radio-frequency identification systems. The use of Licalloy sheets causes a significant increase in transmission distance of magnetic field lines, resulting in an increase in antenna sensitivity at a commercial high carrier frequency of 13.56 MHz. A radio-frequency identification system using the Licalloy sheet has been used in NTT DoCoMo mobile telephones. Very recently, another type of soft magnetic powder cores has been developed in Fe-Nb-B-Si, Fe-Nb-B-P, and Fe-Nb-B-Si-P systems in collaboration with our group and NEC TOKIN Corporation (Matsumoto et al. 2007). The new magnetic powder cores have been named SENNTIX and can be characterized to exhibit the lowest core losses among all types of soft magnetic powder cores developed to date. The use of SENNTIX-II powder cores in the Fe-Nb-B-P system has enabled us to reduce more than 50% core loss compared to existing metal powder and reduce thermal energy loss in personal computers, resulting in the extension of battery life time of notebook personal computers.

Therefore, the SENNTIX powder cores have been supported as Next Generation 2009 Reference Design by major power international corporation suppliers. As a result, the SENNTIX powder cores have been produced on a large number scale of several million pieces per month at NEC TOKIN Vietnam and China factories. Fe–Ni–Cr–Mo–B–Si alloy powders produced by water atomization have been commercialized as Amo-beads (Inoue et al. 2003). The application fields are extended to shot peening balls and fine precise polishing medium. The glassy alloy balls have the advantages of much longer endurance times as compared with those for cast steel shots and high speed steel shots. By using the high-velocity powder-spray-coated layer technique, Fe-based glassy alloy-coated layer has been produced on various metallic alloy substrates. Fe–Cr–Mo–C–B glassy alloy-coated layer exhibits better corrosion resistance than SUS304 plates, higher Vickers hardness than hard chromium plates, and better wear resistance than SKD tool steels and FC cast iron (Sugiyama et al. 2007). Owing to these advantages, the glassy alloy-coating technique has been applied to surface glassy alloy layers inside solder-melting vessels in continuous solder casting machines of 50 cm in diameter and 34–40 cm in height.

6. Conclusion

It is concluded that bulk glassy alloys in Zr-, Fe-, and Ti-based systems have attracted increased interest as various types of functional materials in practice and their application fields will become significantly extended in the near future because of useful engineering values resulting from the simultaneous achievements of novel atomic configurations, unique multicomponent alloy compositions, various bulk forms, Newtonian flow deformability, and net casting formability.

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Figures

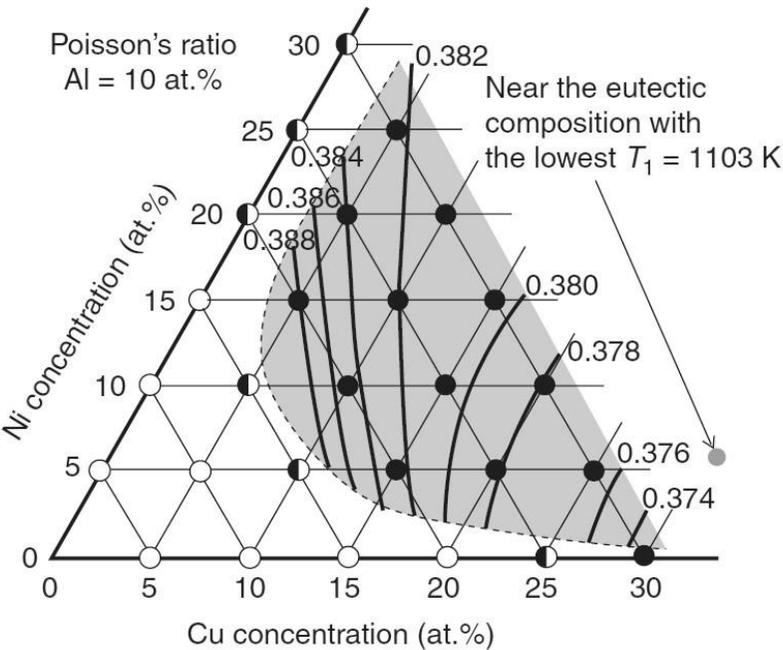


Figure 1 Compositional dependence of Poisson's ratio of Zr–Al–Ni–Cu bulk glassy alloys.

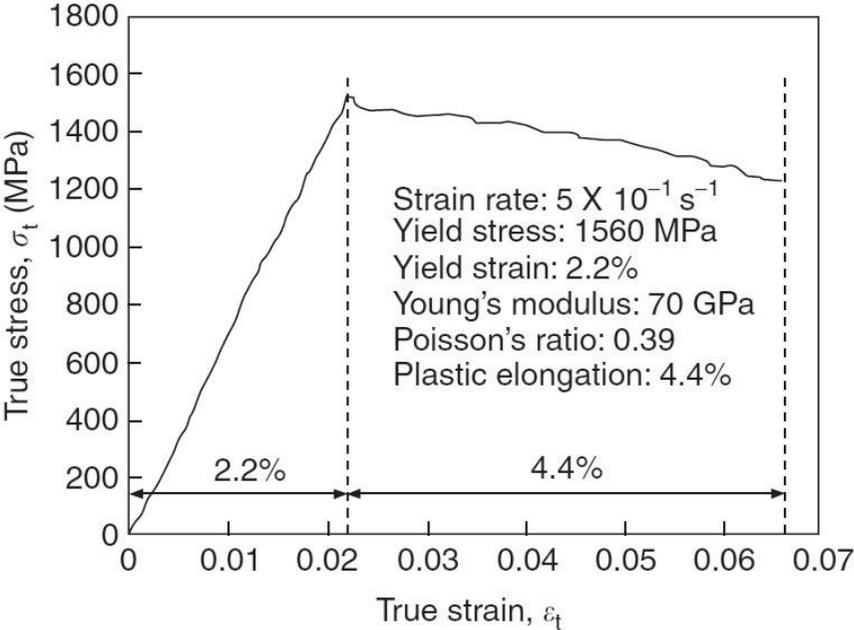


Figure 2 Tensile stress-elongation curve of $\text{Zr}_{70}\text{Al}_8\text{Ni}_{16}\text{Cu}_6$ bulk glassy alloy rod.

Tables

Table 1 Typical bulk glassy alloy systems reported to date and calendar years when the first paper or the patent of each alloy system was published.

Nonferrous	Year	Ferrous	Year
Zr-(Ti,Nb,Pd)-Al-TM	1995	Fe-(Al,Ga)-(P,C,B,Si,Ge)	1995
Pd-Cu-Ni-P	1996	Fe-(Nb,Mo)-(Al,Ga)-(P,B,Si)	1995
Pd-Ni-Fe-P	1996	Fe-(Zr,Hf,Nb)-B	1996
Pd-Cu-B-Si	1997	Fe-Co-Ln-B	1998
Ti-Ni-Cu-Sn	1998	Fe-Ga-(Cr,Mo)-(P,C,B)	1998
Cu-(Zr,Hf)-Ti	2001	Co-Ta-B	1999
Cu-(Zr,Hf)-Ti-(Y,Be)	2001	Fe-Ga-(P,B)	2000
Cu-(Zr,Hf)-Ti-(Fe,Co,Ni)	2002	Ni-Zr-Ti-Sn-Si	2001
Ti-Cu-(Zr,Hf)-(Co,Ni)	2004	Fe-Si-B-Nb	2002
Ca-Mg-Zn	2004	Co-Fe-Ta-B-Si	2003
Pt-Cu-P	2004	Fe-(Cr,Mo)-(C,B)-Ln	2004
Pd-Pt-Cu-P	2005	Ni-Pd-P	2006
Zr-Cu-Al-Ag	2006	Ni-Pd-P-B	2007
Zr-Cu-Al-Ag-Pd	2007	Fe-Si-B-P	2007

Table 2 Alloy compositions and fundamental properties of typical Zr-based bulk glassy alloys in Zr–Cu–Al, Zr–Al–Ni–Cu and Zr–Cu–Al–Ag systems.

Alloy	D_{\max} (mm)	T_g (K)	T_x (K)	T_i (K)	E (GPa)	ε_y (MPa)	σ_y (MPa)	CUE (kJ/m ²)
Zr ₅₀ Cu ₄₀ Al ₁₀	14	706	792	1092	88 ^a	2.1 ^a	1860 ^a	104
Zr ₅₅ Cu ₃₀ Ni ₅ Al ₁₀	30	683	767	1163	90 ^a	2.0 ^a	1830 ^a	125
Zr ₆₀ Cu ₂₀ Ni ₁₀ Al ₁₀	20	662	754	1164	80 ^a	2.2 ^a	1750 ^a	87
Zr ₆₅ Cu _{17.5} Ni ₁₀ Al _{7.5}	16	625	750	1164	82	1.9	1528	85
Zr ₄₈ Cu ₃₆ Al ₈ Ag ₈	25	683	792	1142	102	1.8	1850	
Zr ₄₂ Cu ₄₂ Al ₈ Ag ₈	14	705	780	1213	108	1.8	1986	

a Tensile test data. The others for E (Young's modulus), ε_y (yield strain), σ_y (yield stress) are data under compression.

Table 3 Alloy systems of Fe-based bulk glassy alloys developed to date.

Fe-based BGAs	Type	Commercial name
Fe–TM–P–C–B–Si	Ferromagnetic	Liquialloy
Fe–Co–B–Si–Nb	Ferromagnetic	SENNTIX
Fe–Co–Ni–Mo–B–Si	Nonferromagnetic	AMO-beads

Fe-based Amorphous Soft Magnetic Alloys with High Saturation Magnetization

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Abstract

Fe-based amorphous alloys with high saturation magnetization up to 1.7 T were synthesized in Fe-B-Si-P alloy system. The amorphous alloys exhibit good soft magnetic properties, such as low coercive force of 3.3-6.2 A/m and high effective permeability of 8300 to 15000. In addition, the present alloys show good bending ductility, even in an annealed state. The combination of good magnetic and mechanical properties makes them promising candidates as magnetic functional materials in the future.

Introduction

Magnetic materials play an increasingly important role in modern industry as an essential part of electric motors, electric propulsion, actuators, sensors and data storage devices. Fe-metalloid amorphous alloys were found to exhibit superior soft magnetic properties (such as lower coercivity, higher permeability and lower core loss) [1, 2]. The good soft magnetic properties are due to the absence of crystal magnetic anisotropy and grain boundaries in amorphous phase. The development of Fe-based soft magnetic amorphous alloys with unique structure, good mechanical properties and superior magnetic properties has attracted much attention in a variety of emerging science and engineering technology [3-5].

Over the past several decades, a large number of studies on amorphous soft magnetic alloys have been carried out and various types of Fe-based amorphous alloys have been developed [6-10]. It is known that Fe-Si-B amorphous alloys have been widely used as magnetic cores in devices requiring low core loss and high permeability, such as distribution and power transformers, motors and high frequency inductors, due to the combination of high saturation magnetization, high

permeability and low core loss. For instance, Fe-Si-B amorphous alloy with trademark of Metglas® 2605SA1 shows high saturation magnetization of 1.56 T, high permeability and extremely low core loss (40% of the core loss of grade M3 Si steel) [11]. In addition to Fe-B-Si system, Fe-based amorphous alloys have been synthesized in various alloy systems such as Fe-B-C [12], Fe-B-P [13], Fe-Si-C [14] and Fe-Si-B-C [15] systems, with the aim of developing good soft magnetic amorphous materials. However, little is known about magnetic and mechanical properties of Fe-rich Fe-B-P-Si amorphous alloys containing Fe contents above 82 at%, though glass-type alloys with distinct glass transition and rather wide supercooled liquid region have been synthesized in ribbon [16] and bulk [17, 18] forms in a Fe content range below 80 at% by our group. The glass-forming ability in Fe-B-P-Si systems is high enough to form bulk glassy alloys with diameters up to 2.5 mm [19]. This quaternary alloy system is believed to be only an alloy system in which bulk glassy alloys can be formed without the addition of any transition metals except Fe by copper mold casting. Consequently, the development of a new soft magnetic amorphous alloy by utilizing the advantage of high glass-forming ability in this alloy system is significant for future progress in nonequilibrium soft magnetic material field.

Recently, there has been an increasing emphasis on the development of modern power electronics with excellent performance, high reliability, small in size and light in weight. It has been required to prepare soft magnetic materials with higher B_s , combined with good soft magnetic properties, high stability and low cost [20, 21]. However, amorphous alloys developed to date show much lower saturation magnetization compared with Si steel or Fe-rich nanocrystalline alloys [22, 23]. In addition, Fe-based amorphous alloys, almost inevitably, become brittle in the process of structural relaxation, which makes them difficult to handle and limits their industrial and commercial applications. At present, when improving energy efficiency and energy conservation becomes a global issue, there has been a strong demand on the development of Fe-based soft magnetic amorphous alloys with high saturation magnetization and good mechanical properties. This paper aims to synthesize Fe-based amorphous alloys with high saturation magnetization above 1.65 T in Fe-B-Si-P alloy system and clarify their magnetic softness and mechanical properties.

1. Experimental Procedures

Alloy ingots of Fe-B-Si-P with nominal atomic composition of $\text{Fe}_{81}\text{B}_{10}\text{Si}_{5.5}\text{P}_{3.5}$, $\text{Fe}_{82}\text{B}_{10}\text{Si}_5\text{P}_3$, $\text{Fe}_{83}\text{B}_9\text{Si}_5\text{P}_3$, $\text{Fe}_{84}\text{B}_{8.5}\text{Si}_{4.5}\text{P}_3$ and $\text{Fe}_{85}\text{B}_8\text{Si}_4\text{P}_3$ were prepared by induction melting high-purity Fe, Si, B elements and prealloyed Fe_3P alloy. The as-quenched ribbons were prepared by a single roller melt-spinning technique in an argon atmosphere. Molten alloys are ejected from the small hole at the bottom of quartz tube onto a rapidly rotating copper wheel with an argon pressure difference of 0.02 MPa. The wheel surface velocity was 40 m/s and the cross section of resulting ribbons was about $0.02 \times 1 \text{ mm}^2$. A high-purity argon atmosphere was used during the induction melting and melt-spinning operations. The thermal properties of as-quenched ribbons were examined by differential scanning calorimetry (DSC) at a heating rate of 0.67 K/s. The structure of as-quenched and annealed ribbons was identified by X-ray Diffraction (XRD) analysis with Cu $K\alpha$ radiation. The B_s and H_c were measured with a vibrating sample magnetometer under a field of 800 kA/m and a DC B-H loop tracer under a field of 800 A/m, respectively. Effective permeability (μ_e) at 1 kHz was measured with an impedance analyzer under a field of 1 A/m. All of the ribbons for magnetic property measurements were annealed at the temperature of $T_x-100 \text{ K}$ for 600 s for improving soft-magnetic properties through structural relaxation. Hardness measurements were performed using a Vickers hardness indenter by applying a load of 0.98 N (100 gf), and the hold time employed was 10 s. The ribbons were bent through 180° and then bent to straight shape. Slip markings generated by hardness tester and the bent surface of the amorphous samples were examined by scanning electron microscopy (SEM).

2. Results and Discussion

The amorphous nature of samples both in the as-prepared and the annealed states (after structural relaxation) has been confirmed by X-ray diffraction technique. As examples, the XRD patterns of the ribbons after structural relaxation are shown in Fig.1. Only broad peaks without appreciable crystalline peaks can be observed, which are characteristic of an amorphous structure. These results indicate that amorphous ribbons with high Fe contents up to 85 at.% are formed in Fe-B-Si-P alloy system. With further increasing Fe content to 86 at.%, the as-spun structure changed to coexistent bcc-Fe and amorphous phases.

DSC curves of the as-quenched Fe-B-Si-P amorphous alloys are shown in Fig. 2. Two exothermic peaks are seen on these DSC curves, indicating that the crystallization takes place through two stages. The onset temperature of the first crystallization peak (T_{x1}) decreases gradually from 760 K to 688 K with increasing Fe content from 81 to 85 at.%. However, no glass transition phenomenon is observed for all the Fe-rich amorphous alloys, though the decrease in Fe content causes distinct glass transition and supercooled liquid region in this alloy system [18]. As similar for T_{x1} , Curie temperature (T_c) of the amorphous phase drops from 633 K to 565 K as the Fe content increases. The variation of T_c may be concerned with the closer approach of Fe atoms to each other, which causes some antiferromagnetic exchange interaction [24]. On the other hand, T_{x2} increases from 802 K to 831 K as Fe increases from 81 to 84 at.% and then decreases to 826 K for alloy with 85 at.% Fe. As a result, there is a tendency for the temperature interval between the two exothermic peaks to increase with increasing Fe content.

To determining precipitation phases corresponding to these exothermic peaks, structures of the alloys subjected to annealing under different conditions were examined by XRD. As one example, the XRD patterns of the as-quenched amorphous $\text{Fe}_{84}\text{B}_{8.5}\text{Si}_{4.5}\text{P}_3$ alloy, as well as the sample annealed for 600 s at 723 K (which is higher than the temperature of the T_{x1}), and 873 K (which is higher than the temperature of the T_{x2}) are shown in Fig. 3. It is obviously seen that the diffraction pattern consists of three peaks after annealing at 723 K, which can be indexed as bcc α -Fe phase. While, the diffraction peaks after annealing at 873 K are identified as α -Fe and tetragonal $\text{Fe}_3(\text{B}, \text{P})$ phases. Thus, the two peaks correspond to the primary precipitation of α -Fe and the decomposition of the remaining amorphous phase to α -Fe and $\text{Fe}_3(\text{B}, \text{P})$, respectively.

The magnetic properties of these glassy alloys were further investigated. Figure 4 shows hysteresis B-H loops and coercivity of the ribbons annealed for 600 s at temperatures of T_x-100 K. The inset (b) depicts the enlarged partial curves of the B-H loops. As is shown, all the loops exhibit the typical soft magnetic character. The B_s value is 1.65 T for the Fe 81 at.% amorphous alloys, and gradually increases to 1.70 T with increasing Fe content to 84 at.%, proving that high Fe content benefits the enhancement of high B_s . For the alloy with 85 at.% Fe, the B_s value decreases to 1.65 T. In order to understand the reason for the change in B_s ,

the magnetization at 0 K and Curie temperature of the alloys should be considered. As the Fe content increases, the magnetization at 0 K increases, while the Curie temperature decreases. The balance between these two trends leads to a maximum in the room-temperature magnetization at about 84 at.% [25].

As shown in Fig.4 (c), the coercivity increases gradually from 3.3 A/m to 6.2 A/m with increasing Fe content up to 84 at.% and then rapidly to 17.4 A/m at 85 at.% Fe. The increase in coercivity seems to be related to the decrease in glass-forming ability with increasing Fe content. That is, the decrease in the degree of structural disorder caused by the decrease in glass-forming ability causes the reduction in homogeneity of disordered atomic configurations, which realizes the increases in the high density of the quasi-dislocation dipole-type elastic stress sources and/or the high pinning force due to the elastic stress [26, 27]. As a result, the coercivity increases and the magnetic permeability decreases with increasing Fe content.

Hardness measurements have been conducted using a Vickers hardness indenter by applying a load of 0.98 N for 10 s. More than three indentations were carried out to obtain the average hardness values. SEM image of the $\text{Fe}_{84}\text{B}_{8.5}\text{Si}_{4.5}\text{P}_3$ alloy ribbon with a slip marking generated by indentation of a Vickers indenter with a load of 0.98 N was shown in Fig. 5. The hardness value calculated by dividing the load by the surface area of the indent is between 780-890 kg/mm², which is much larger than that of the common used Si-steels, indicating the possibility of much better wearability. In addition, a number of slip-steps markings are seen in the vicinity of the indentation for the alloys. The generation of slip-steps markings and the absence of appreciable crack also suggest that the alloys are ductile enough to avoid catastrophic fracture [28].

For bulk rods or thick sheets of metallic glasses, it has been reported that brittle fracture happens almost immediately at the beginning of bending deformation, in conjunction with the mechanism and criterion for the brittle fracture [29, 30]. Besides, there are a number of data on extremely brittle nature for nanocrystalline Fe-based alloys obtained upon annealing amorphous alloy ribbons, and the mechanism for the brittle nature has also been investigated [31, 32]. In this paper, we have noticed that the present alloy ribbons exhibit better bending ductility in as-quenched and annealed states. Their ribbons were bent

through an angle of 180° and then bent back to the original straight shape, but any trace of fracture was not recognized for the ribbons. As an example, Fig. 6 shows SEM images revealing surface appearance of both sides of the crease marks for the Fe₈₂B₁₀Si₅P₃ amorphous alloy annealed at 647 K for 600 s. A number of slip bands can be seen in the vicinity of the concave (Fig. 6 (a)) and convex (Fig. 6 (b)) marks. The bending experiments demonstrate that the alloys show good bending ductility, even in the annealed state. The good bending ductility is useful for Fe-based amorphous ribbons for using as magnetic cores, which allows them to be easily wound into various cores in electrical-magnetic devices.

Table 1 summarizes thermal (T_{x1} , T_{x2} and T_c) and magnetic properties (B_s , H_c and μ_e) of the Fe-B-Si-P amorphous alloys. One can see that the alloys with Fe contents of 81-84 at.% show high B_s of 1.65-1.70 T, rather low H_c of 3.3-6.2 A/m and high μ_e of 8 300-15 000. In addition to the good magnetic properties, the Fe-B-Si-P alloys exhibit high hardness values and good bending ductility. Moreover, the alloys possess a great economical advantage because they contain only inexpensive metalloid elements expect for Fe. Therefore, the present Fe-rich amorphous alloys should have a promising application as magnetic cores. However, the optimum technique parameters for mass production should be further explored.

Conclusions

We examined the formation, thermals stability, magnetic characteristics and mechanical properties of Fe-B-Si-P amorphous alloys with high Fe contents from 81 at.% to 85 at.%. The alloys show high saturation magnetization up to 1.70 T, good magnetic softness, high hardness values and good bending ductility even in the annealed state where the optimum magnetic softness is obtained. Moreover, the raw materials of the alloys are low-cost and high-productivity. Therefore, the Fe-B-Si-P amorphous alloys with good magnetic properties and bending ductility are considered to be an important candidate for magnetic core materials.

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Figures

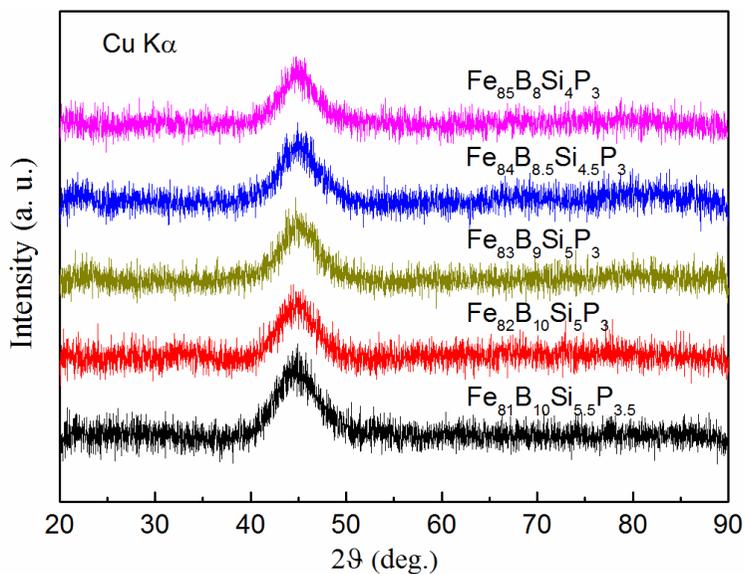


Fig. 1 XRD patterns of the Fe-B-Si-P ribbons after structural relaxation

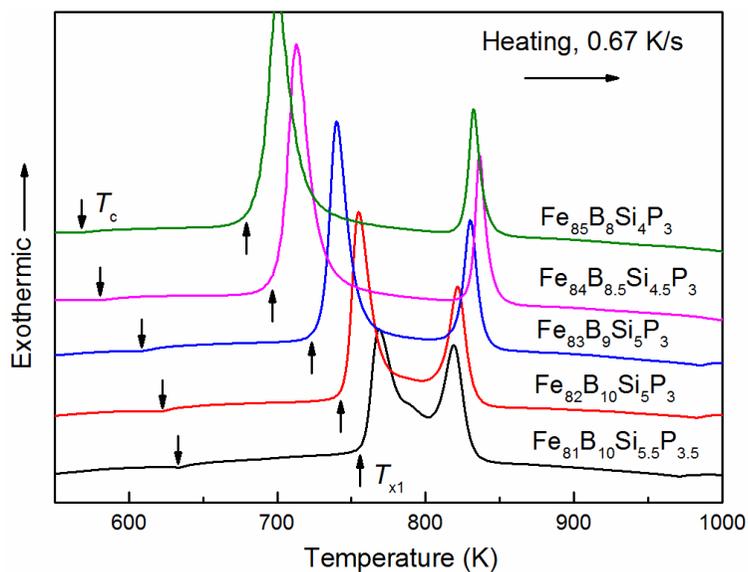


Fig. 2 DSC curves of the as-quenched Fe-B-Si-P amorphous alloys

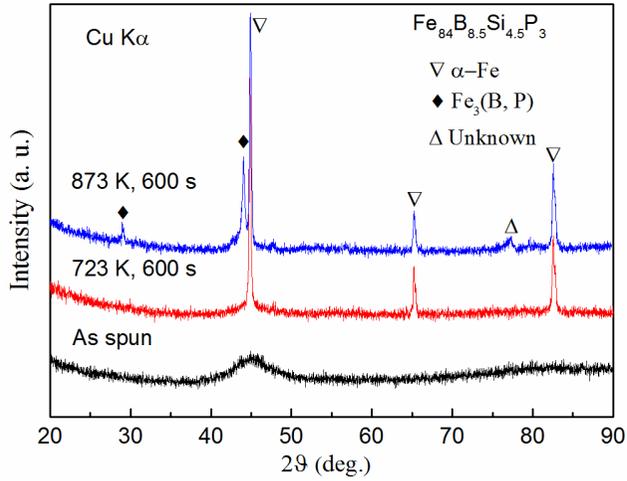


Fig. 3 XRD patterns of as-quenched and annealed $\text{Fe}_{84}\text{B}_{8.5}\text{Si}_{4.5}\text{P}_3$ alloys

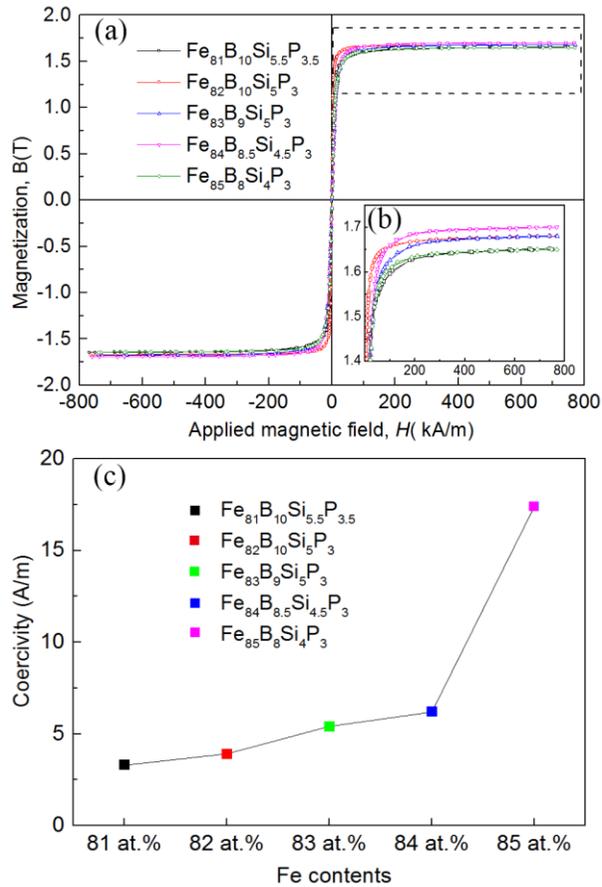


Fig. 4 (a) Hysteresis B-H loops, (b) enlarged partial curves of the B-H loops and (c) coercivity of the ribbons annealed for 600 s at temperatures of T_x-100 K

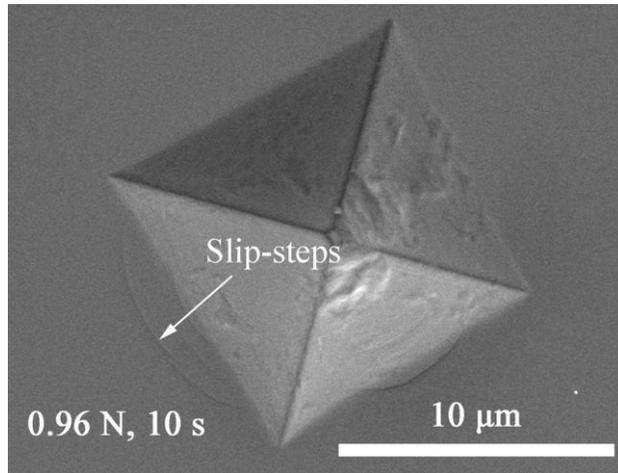


Fig. 5 SEM image of the Fe₈₄B_{8.5}Si_{4.5}P₃ alloy ribbon with a slip marking generated by indentation of a Vickers indenter

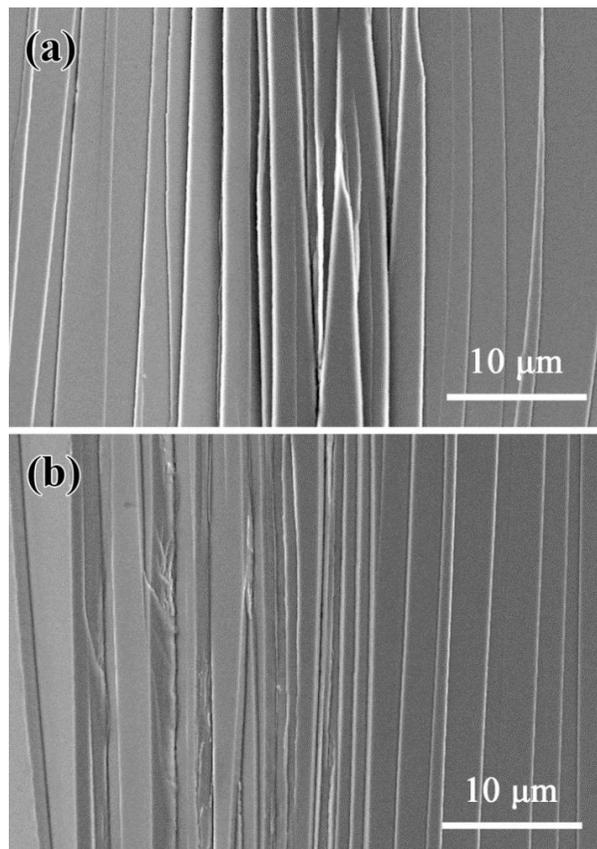


Fig. 6 SEM images revealing surface appearance of the concave (a) and convex (b) of the crease marks for the Fe₈₂B₁₀Si₅P₃ amorphous alloy annealed at 647 K for 600 s.

III. Mitigating Heat-island Phenomenon

Mechanism of Improving the Thermal Environment Caused by the Building Greening

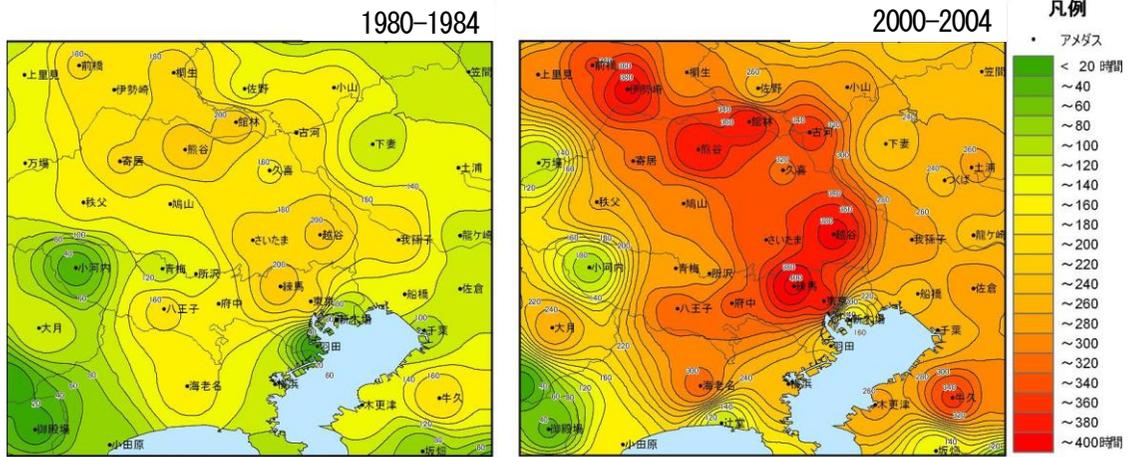
Hiroataka Suzuki

Introduction

Recently, in large cities, such as Tokyo, “heat-island phenomenon” has become tangible. The temperature in city area is higher than in surrounding rural areas by a few degrees. It looks just like an island.

Fig.1 is a map to show the places where the temperature reached over 30 °C in Kanto region, Japan. The color pattern on the right side denotes the cumulative time in hours over 30 °C per year. The left figure shows the average cumulative time in hours of 5 years from 1990 to 1994, and the right one shows from 2000 to 2004. These figures show that the most of the region is under 200 hours from 1990 to 1994, while from 2000 to 2004, most of the region is more than 300 hours. The change of the average temperature in Tokyo for 100 years, from 1990 to 2000 was shown by **Fig.2** Average temperature has increased by 3 °C approximately. The increase of the average temperature caused by the global warming is considered to be 0.7 °C. So it is supposed that more than 2 °C were caused by the heat-island phenomenon.

I will point out 3 reasons for the heat-island phenomenon, as shown by **Table 1**. The first reason is decrease of the greenery space and the body of water. This is caused by the urban development, and increasing ground surfaces paved with concrete or asphalt. The second reason is increasing waste heat generated by air-conditioners of buildings and automobiles. The third reason is the blocking of wind due to the buildings of the cities.



the places where the temperature reached over 30 °C in Kanto region, Japan h / year
 (Data from the Ministry of Environment)

Fig.1 Increase of °Manatsubi

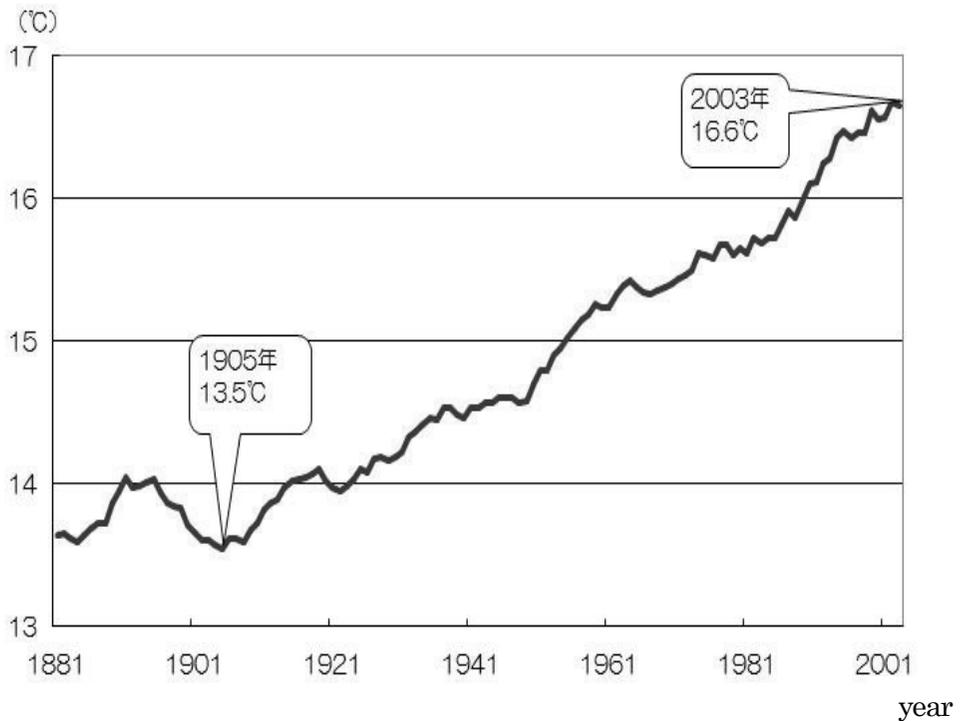


Fig.2 The Change of the Average Temperature in Tokyo

(The Source : Japan Meteorological Agency)

Table 1 The Main Cause of the heat-island phenomenon

Category	Main Cause
Artificial ground surface coverage	Decrease of evaporation caused of reduction in greenery space, water surface, agricultural lands.
	Increase of absorption and storage of heat, caused of increase of pavements and buildings.
Increase of artificial disposal heat	Disposal heat from buildings
	Disposal heat from factories
	Disposal heat from automobiles
Change of the urban form	Poorly ventilation
	Decrease of large greenery space and water surface

(Data from the Ministry of Environment)

1. The Trend and Tasks of the Technology Development on the Wall Greening

Wall greening is attracting increased attention as an effective method for mitigating the environmental loads in urban areas and thus preventing the heat island phenomenon and global warming. The purpose of this study is to obtain the fundamental data needed for the examination of the direction of technology development for the future promotion of wall greening in urban areas and the object and range to be mainly grappled with in the field of research and development. The investigation was conducted by a questionnaire survey on 119 private companies which are grappling with the greening, development and utilization of rooftop spaces, in order to grasp the consciousness of those companies and their technical staffs about the market of wall greening, and the possibility of propagation, and sort out the technological tasks. The survey revealed that (1) the companies expect the wall greening market to expand, (2) the technical staffs recognize that the important thing in the technology development for wall greening is the quantification of environmental improvement effects the reduction of the costs of constructing and maintaining the green walls, and (3) the technical

staffs also recognize the differ of the sites on which wall greening can be applied and the possibility of propagation among 6 types of wall greening (①utilization of natural ground as the base of plants, ②utilization of flames for support as well as natural ground base, ③utilization of planters on each story, ④utilization of planters with flames for support on each story, ⑤installation of greening panels, ⑥utilization of concrete blocks for greening).

2. The effect of the wall greenery for the reduction of the heat flux and the accumulated volume of heat flow toward indoor from the wall in summer

The effect of the wall greenery to reduce the heat flux and the accumulated volume of heat flow toward indoor from the wall for 24 hours in summer was analyzed for 3 different types of buildings where heat flux and other data were measured in the past. The reduction of the heat flux by the wall greenery at the time when the heat flux through the wall without vegetation was maximum were from 84.5 to 13.6 W(watt)/m² and from 98.7 to 61.6 % in ratio. The reduction of the accumulated volume of heat flow for 24 hours were from 1186.8 to 265.5 KJ/m² and from 86.4 to 59.3 % in ratio.

Fig.3 shows the radiant balance and heat balance on a building wall. The left side figure shows that /the short wave radiation and long wave radiation could incident on the wall. And the reflected solar radiation and radiant heat is radiated

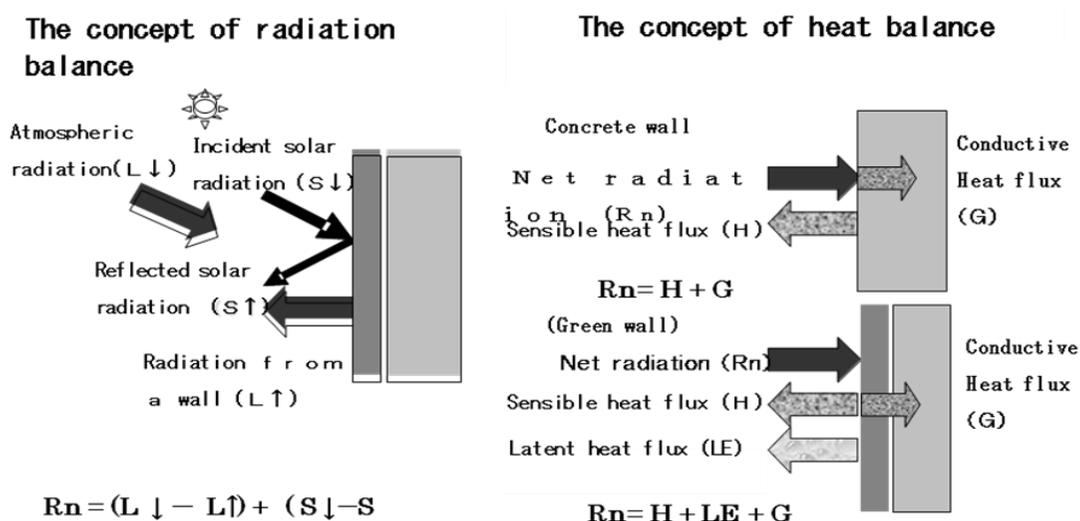


Fig.3 The Concept of Radiation Balance and Heat Balance

from the wall surface outside of a building. And the total sum of shortwave and longwave balance of the incident radiation and reflect radiation is called as the radiation balance, which is equal to the net radiation.

$$Rn = (L\downarrow - L\uparrow) + (S\downarrow - S\uparrow)$$

Rn : Net radiation (W/m^2), $L\downarrow$: downward long wave radiation (W/m^2),
 $L\uparrow$: upward long wave radiation (W/m^2), $S\downarrow$: downward solar
radiationn(W/m^2), $S\uparrow$: upward solar radiation (W/m^2)

The right side figure shows the heat balances on the concrete wall and greening wall. When the temperature of the surface of the wall is higher than the air temperature, sensible heat flux is transferred from the wall into the air. On the green wall, the latent heat flux is consumed by the evaporation from plants.

$$Rn = H + LE + G$$

Rn : Net emission (W/m^2), H : Sensible heat flux (W/m^2), LE : Latent heat flux (W/m^2), G : Conductive heat flux (W/m^2).

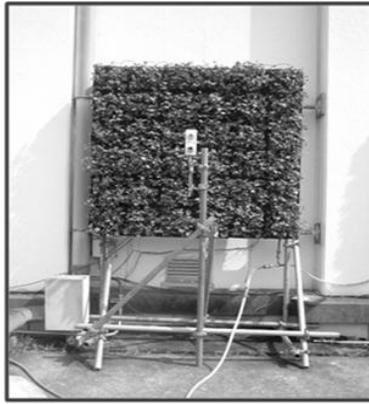
Then, I will report the experiment on the wall greening, which I have conducted. These are three types of the model wall which were used on the experiment, as shown by **Photo.1**. The left photo is a concrete wall, painted white. The middle one is a green wall, covered with a kind of ivies, named *Hedera Helix*. The right one is a green wall, also covered with a kind of ivies, named *Euonymus fortunei*. The green wall is 1.8m high, and 1.8m wide.

The next **Photo.2**, taken by an infrared camera, shows the changes of the surface temperature of the each model wall. At 5 o'clock, it was clarified that both of the surface temperatures of the greening panels were lower than that of the concrete wall. At 9 o'clock, the surface temperature of *Hedera helix* wall was **Fig.3** shows the radiant balance and heat balance on a building wall. The left side figure shows that /the short wave radiation and long wave radiation could incident on the wall. And the reflected solar radiation and radiant heat is radiated

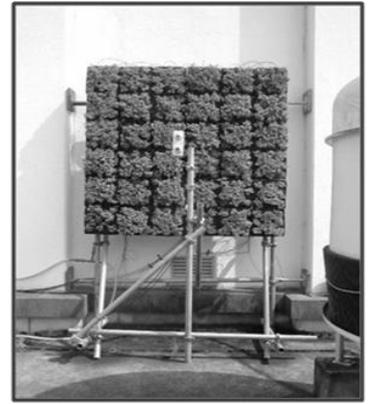
Fig.3 shows the radiant balance and heat balance on a building wall. The left side figure shows that /the short wave radiation and long wave radiation could incident on the wall. And the reflected solar radiation and radiant heat is radiated



Concrete wall
(White painted)



Hedera herix



Euonymus fortunei

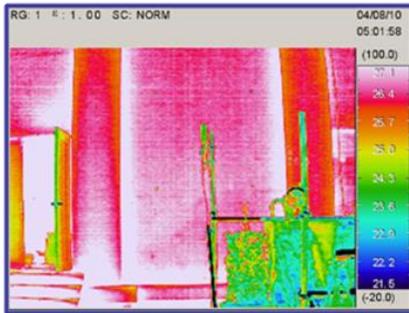
Photo.1 Examination bodies used by the experiment

3. Estimation of the effects on the thermal environment for pannel-type wall greening system by the transpiration measurement

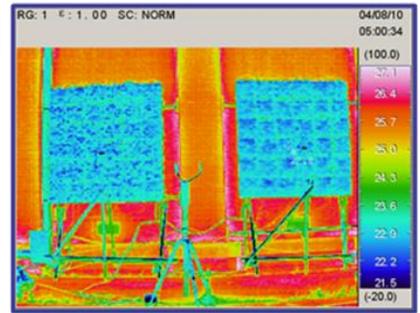
This study aimed to quantitatively assess the effects of wall greening systems in mitigating the thermal environment by measuring the transpiration from wall panels on which *Eurnonymus fortunei* was planted, and calculating the latent heat flux from the transpiration measurements. The analysis showed that 1) the transpiration from the panels, which used peat moss as the growing media, was about 3.6 kg/m² (3.6 mm), of which 60% or about 2.2 kg/m² (2.2 mm) was from the plants, and there was a positive correlation between the latent heat flux and the net emission, and the latent heat flux by transpiration from the panels was about 60% of the increment in net emission. The study suggests that the effects of a wall greening system in controlling latent heat and thus mitigating the thermal environment can be quantitatively assessed by calculating the latent heat flux of panels from transpiration measurements and analyzing the heat balance. In order to evaluate the effects of mitigating urban heat island by wall greening, basic experiment about evaporation characteristics and heat balance of greening system were carried out. At heat balance analysis, sensible heat flux is calculated using heat transfer coefficient estimated by measurement with SAT (Sol-air Temperature) meter. The results of heat balance analysis show the latent heat

(Aug.10th,2004)

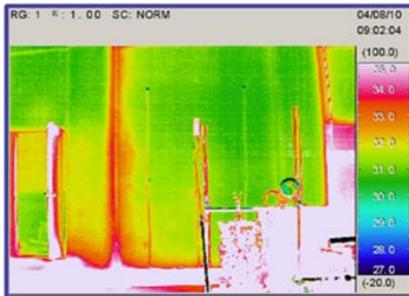
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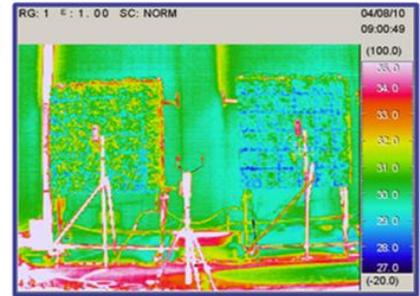
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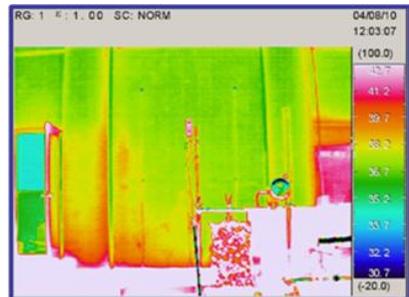
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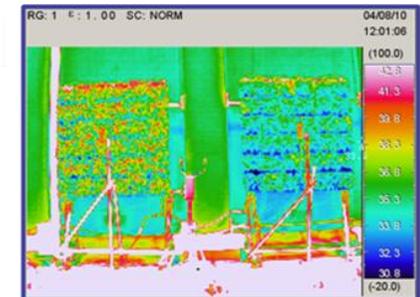
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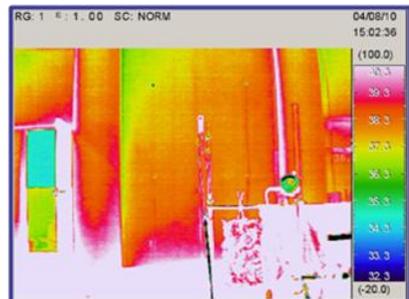
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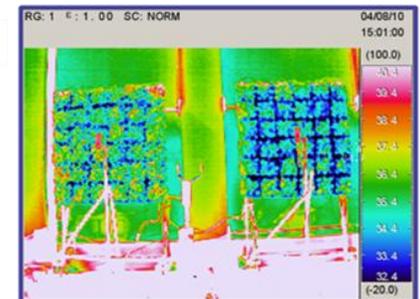
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Concrete wall (white painted)

Left: *Hedera herix*
Right: *Euonymus fortunei*

Photo.2 The wall surface temperature printed by the infrared camera

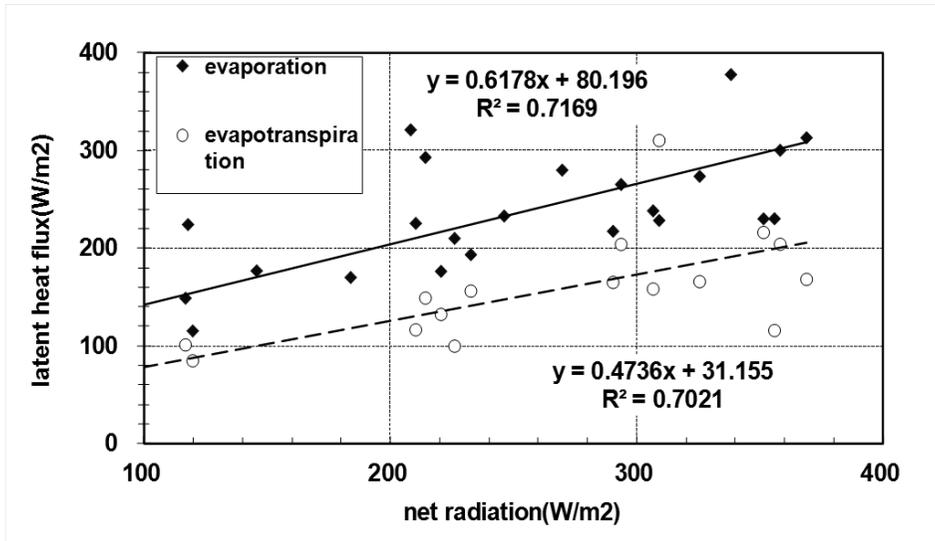


Fig.5 Relationship between latent heat flux and net emission (*Euonymus fortunei*)

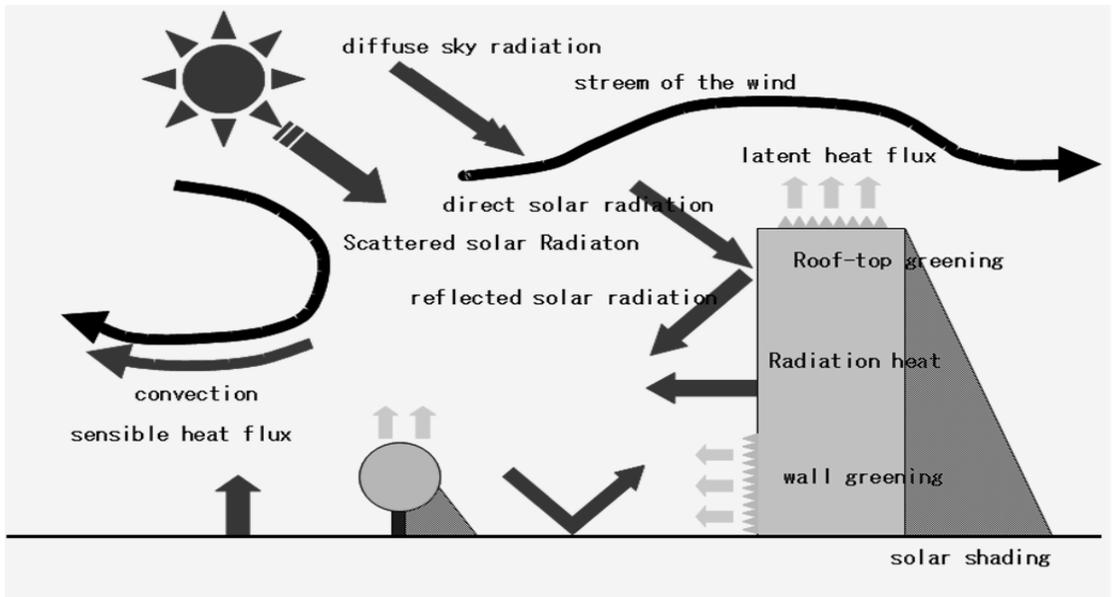


Fig.6 Mechanism of Forming the Thermal Environment

consumption of evapotranspiration at greening system to prevent increase sensible heat. And it is able to evaluate the effects by wall greening system using evaporation efficiency as an index of evaporation ability. 2.6. Simulation of the Effect of Building Greening on Thermal Environmental Improvement by Computational Fluid Dynamics Analysis.

This study aims to grasp the effect of the thermal environment improvement by building greening, which is as one of measures to a heat island phenomenon in a city, it was evaluated quantitatively by using indexes of MRT (Mean Radiant Temperature) and SET* (Standard Effective Temperature), being applied CFD.(Computational Fluid Dynamics) method with coupled simulation of convection, radiation and moisture.

As a result, compared with the case of no planting, MRT could reduce 4.5 °C and SET could also reduce 1 °C as the maximum, in the case of the wall greening combined with the ground surface and the roof top greening, thermal improvement effect could be recognized in the model block.

Outdoor thermal environment is composed of various elements, such as solar radiation, wind, damp, and waste heat from buildings, as shown by **Fig.6**. These elements are interrelated. For example, on the surface of a building, solar radiation is reflected, and the heat from the surface of the building is radiated, and at the same time, the building receives the long wave radiation, and radiates the heat. By greening the roof-top and the wall, latent heat flux is released by evaporation, and it could be expected to control the sensible heat flux. In order to analyze and estimate the outdoor thermal environment synthetically, it would be necessary to analyze various physical phenomena simultaneously. They could be formed by the flow of air, radiation environment, and humidity and so on. We adopted the CFD analysis method in order to simulate the thermal environment of the model blocks. They have greenings which are installed in different ways. To execute the numerical analysis, we adopted 3 cases to grasp the characteristics of the compound greenery effects. Followings are the cases.

(Case 1) No greening

(Case 2) Ground and roof-top are covered with greenery. 20% of each site area is covered.

(Case 3) (Case 2) + Both south side and east side of the buildings' walls are covered with greenery from the ground level up to 30m.

As the input climate condition, we used that of 13 o'clock , Aug.5th of 2003. It is derived from the AMeDAS (Automated Meteorological Data Acquisition System) of Japan Meteorological Agency.

Then we made a model of an actual existing city block on the computer. Selected city block was Otemachi 1chome, Chiyoda-ku, Tokyo, which is a representative example of a business district in the center of a large city. The form of this city block is rectangular, as shown by Fig.7. Width in east and west is about 200m, and width in south and north is about 120m. The placement and condition of the Model was shown by **Table 2**. In this block, there are 3 main buildings. They are about 70 to 100m height, and they have public open spaces. We incorporated the forms of the buildings and their placements to the model precisely, by using the GIS data.

Fig.8 shows the MRT distribution map, this is the output of the simulation. MRT (Mean Radiant Temperature), which is one of the indexes which shows heat feeling, is showed by the temperature, averaging the heat radiation from all direction. In the case 1, at the center of the block, the temperature was 39 degrees Celsius. And at the south side and west side of the building in the south-east side of the block, there were bands where the temperature was 42 degrees Celsius. In the case 2, at the center of the block, the temperature was 37.5 degrees. And there were some areas where the high temperature was more than 40 degrees, at the south side of the building in the south-east side of the block. In the case3, by adding the wall greening, the low temperature area was formed at the center of the block. 3 degrees lower than the case2, and 5 degrees lower than the case1.

By greening the roof-top and the ground surface, the high temperature area shrank remarkably, and the temperature was lower than the case 1 by 3.0 degrees.

Conclusion

- (1) Building greening could be a useful way to restore the greenery space. It would improve the ground surface in artificial cities. It could be a convenient method for coexistence between nature and mankind.
- (2) Mitigating the radiant heat by evaporation effect of plants, and decreasing the conduction heat into a building by screening the solar radiation.

It could be a useful method to improve the thermal environment in cities.

- (3) This simulation analysis could be useful to quantify and evaluate the improving effects to the thermal environment by building greening.

Table 2 The placement and condition of the Model

Item	Numerals
①Block Area	32,356m ²
②Building Area	22,317m ²
③Total Floor Area	386,026m ²
④Open space Area	10,039m ²
⑤Building to land ratio	69.0%
⑥Floor area ratio	1,193.0%
⑦Open space ratio	31.0%
⑧Land use	Commercial area

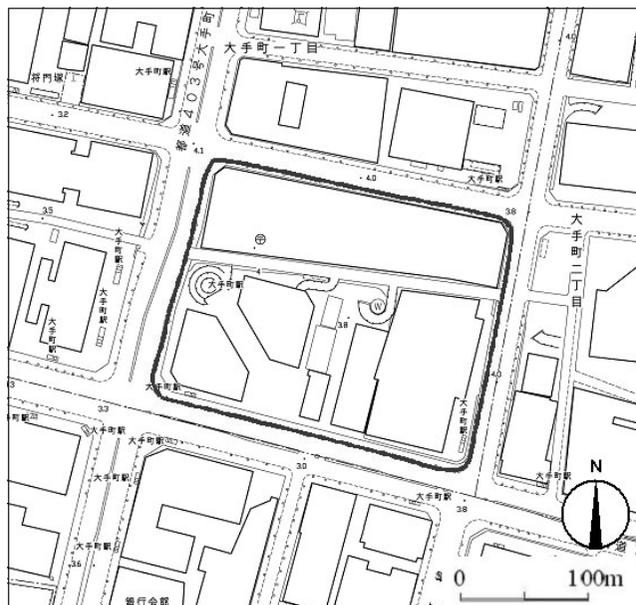
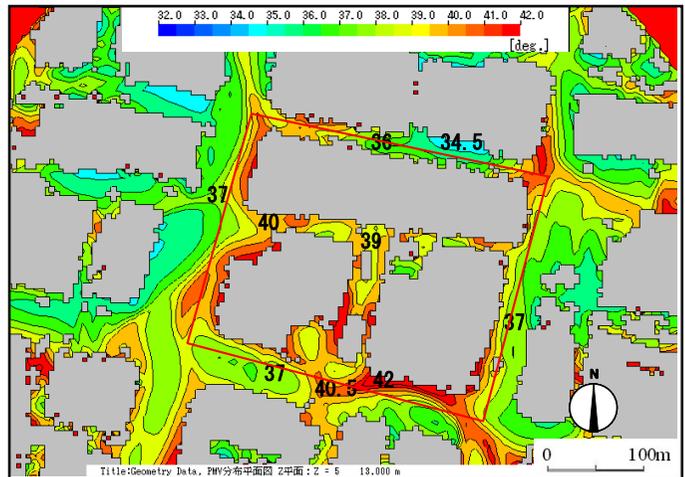
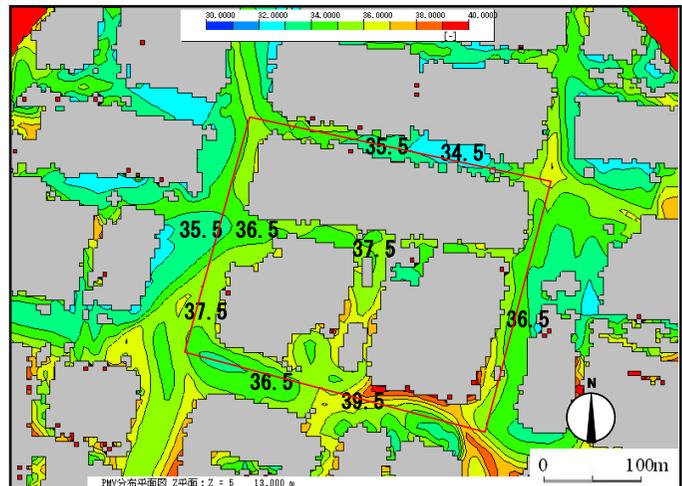


Fig.7 Objective Actual Block (Otemachi)

Case 1 without greening



Case2 20% greening of the roof-top and ground surface



Case3 Case2+30m greening of the south and east side of the buildings

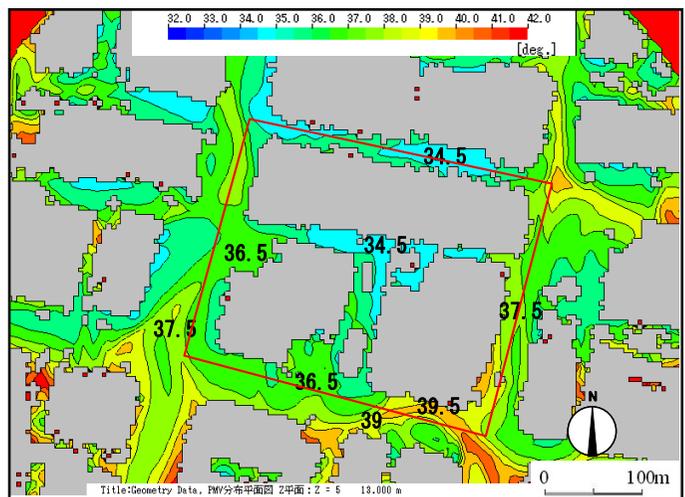


Fig.8 MRT Distribution Map

Estimating the Thermal Environment Improvement Effects of Wall Greening

Hiroataka Suzuki

Abstract : This study is intended to quantitatively assess the thermal environment mitigation effects of wall greening, which is attracting attention as a countermeasure against the heat island phenomenon in cities, by measuring the surface temperature and MRT of panels covered with vegetation and of concrete walls (painted white). As a result, the surface temperature of panels was lowered about 2 to 4°C outside peak time, and the MRT was also about 11°C lower at peak time. Next the evapotranspiration from wall panels was measured and the latent heat flux was calculated based on the measurement data. The analysis showed that the evapotranspiration from the vegetation on the panels was about 4.1kg/m² (4.1mm), and the latent heat flux from the panels was about 60% of the net heat emission. The study suggests that it is possible to quantitatively assess how effectively wall greening decreases sensible heat flux.

Keywords : heat island, wall greening, thermal environment, MRT, latent heat flux , evapotranspiration

1. Background and Purpose of the Study

The heat island phenomenon has become a conspicuous problem as a result of the increase of artificial heat disposal as a result of expanding the ground surface area covered by concrete or asphalt and decreasing greenery spaces and the water surfaces, and the use of cars and air conditioners in an urban regions. The "Outline of the Policy Framework to Reduce Urban Heat Island Effects" was enacted in March 2004 by the Inter-Ministry Coordination Committee to Mitigate Urban Heat Island. These measures must now be undertaken aggressively and as quickly as possible.

It is assumed that effective ways to mitigate the heat island effect are to increase greenery spaces in cities as a measure to improve the coverage of their ground surfaces, and that in city areas where land use has been highly

concentrated, it is necessary to promote the greening of roof-tops and walls of buildings on private land which occupies most of the land in cities.

Compared to the technological progress and wide application of roof-top greening, wall greening is still relatively undeveloped.

A technological challenge to developing and popularizing wall greening in the future is, as Shimomura¹⁾ has pointed out, stably supplying and clarifying the growth characteristic of plant materials which can be used for wall greening, by for example, rearranging species names and variety names, developing methods of measuring their adhesive power on various surface structures and grasping the growth characteristic of plants.

In addition, Muto²⁾ has, based on hearings using the evaluation grid method, pointed out problems from the visual and psychological perspectives related to planning and design, such as building uses, design, plant forms and intervals. The Development Bank of Japan³⁾ has pointed out the difficulty of uniformly sprinkling water, and pruning and other maintenance methods, as challenges facing panel-type wall greening and climbing up/sagging-type wall greening, and has also pointed out a lack of information concerning the quantitative effects of wall greening and contents and expense of maintenance at the time of construction as problem hindering the spread of the method.

The anticipated effects of concrete thermal environment improvement by building greening are the reduction of sensible heat flux by increasing the latent heat flux through evapotranspiration from plants and basement soil. As an attempt to evaluate transpiration effects of plants used for wall greening, Nojima⁴⁾ tried to estimate the quantity of transpiration by measuring transpiration velocity, but he failed to verify any correlation of his estimate with actual measured values. In addition, Hagishima⁵⁾ proposed to quantitatively estimate transpiration of wall greening based on an experiment using the SAT meter, but he did not accumulate sufficient data nor provided positive evidence.

Therefore, this study was intended to quantitatively evaluate the thermal environment improvement effects at the outside of a building. We compared surface temperature and MRT on wall greening panels greened using two kinds of plants, *Euonymus fortunei* and *Hedera herix*, and on a concrete wall (the white painted). We then examined the sensible heat flux reduction effect on wall greening panels, based on the latent heat flux which was calculated based on the

quantity of evapotranspiration measured by weight.

2. Method of Study

2.1 The establishment of experimental devices

We set up two green panel specimens on the wall surface of a south-facing building above first floor roof-top of a laboratory building at the Building Research Institute. The green panel specimens were installed above 1 to 3m from the roof-top surface and 0.5m from the wall surface of the building.

In addition, a concrete outer wall surface (painted white) of a laboratory building was used as the non-covered concrete wall surface to compare it with wall greening surface. Each green panel specimen had a peat-moss base (length 30cm, width 30cm, thickness 8cm). Each Panel was 1.8m \times 1.8m in size, consisted of a total of 36 specimens which were arranged in a square with 6 specimens vertically and 6 specimens horizontally.

The covering thickness of the plants was about 8-12cm. It could be confirmed by eyes that there were no great differences between the state of plant growth of the units which constituted one green panel. The specimens were delivered to the test site on July 25, 2005. To water the plants on the specimens, we installed a drip-type sprinkler on the green panels for 10 minutes at 18:00 once every 4 days except rainy days so that base of a panel would not dry. Figure 1 shows the layout of the specimens measuring devices, and Photo 1 shows how each specimen was installed.

2.2 Measurement method

The following is the specific measurement method.

- ① A long-short wavelength radiometer and a glove thermometer were set 0.5m from the wall surface of the specimen and about 2m above and approximately in the middle of the roof top.
- ② T-type thermocouples (ϕ 0.2mm) were installed on five points, four corners and the center of each specimen, in order to measure the surface temperature of the specimens and the concrete wall. In addition, to exclude the impact of direct solar radiation on the installation parts, we applied white elastic paint the same color as the concrete wall from the top of the aluminum tape on the

concrete wall installation surface.

- ③ We also installed a thermo-hygrometer, an anemo-scope meter, and a pyrliometer about 3m apart from the green wall specimens.
- ④ We installed measurement devices on July 25, 2004 and performed automatic measurements from July 28th to August 28. We recorded the measurement results at one-minute intervals.
- ⑤ In order to grasp the state of plant growth on each unit of the green panel specimen, after measurement, all the leaves of each 30cm*30cm unit were removed and the leaf areas were read with a scanner. A unit, equal to the ones that constituted the green panel was also installed near the specimens to be used for weight measurement . (cf. Photo. 1)

The state of installation of the green panels and measurement devices are shown in **Fig.1**.

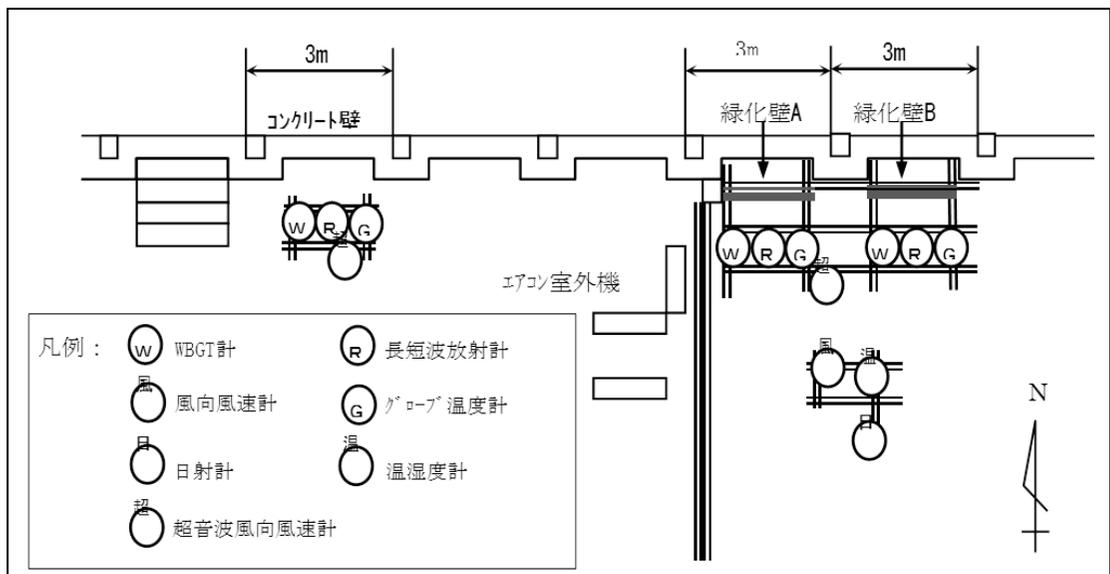
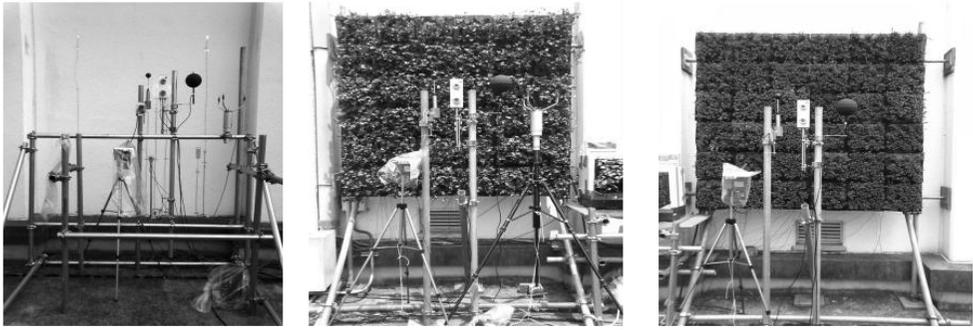


Fig.1 Measurement machineries placement



left : concrete wall (white painting) center : *Hedera herix* right : *Eunonymus fortunei*

Photo. 1 State of installation of the specimens



Photo.2 The measurement situation of quantity of evapotranspiration using electronic scales

Table 1 Measurement device list

Measured Item	Measurement Machinery Name	Maker Name (Model No.)	Qty.
Temperature Humidity	Thermometer/Hygrometer	Vaisala Co., Ltd. (HMP45D)	1
Wind direction Wind velocity	Anemoscope/Anemometer	Ogasawara Instrument Co., Ltd. (CW105)	1
	Supersonic Anemoscope/ Anemometer	Eko Instruments Co., Ltd. (MR -130)0	2
Quantity of sunlight	Pyrheliometer	Prede Co., Ltd.(PCR -02)	1
Quantity of long wave emission Quantity of radiation Quantity of incident sunlight Quantity of reflectedsunlight	Length Wave Radiometer	Eikoh Seiki Instruments Co., Ltd.(MR -500)	3
Blackball temperature	Glove Thermometer	Prede Co., Ltd.(BST131)	3

3. Results

3.1 The general weather outlook

The change of temperature, humidity, intensity of solar radiation and wind velocity are shown in **Fig. 2** as climatic conditions during the seven days from August 16 to August 22. Although rain fell from the previous night to 1:00 only on August 16, the highest temperature was over 30 degrees on four days from August 16 to 22. The highest temperature during the measurement period was 33.6°C on August 20, the lowest temperature was 21.6°C on August 17, and the average temperature was 27.3°C.

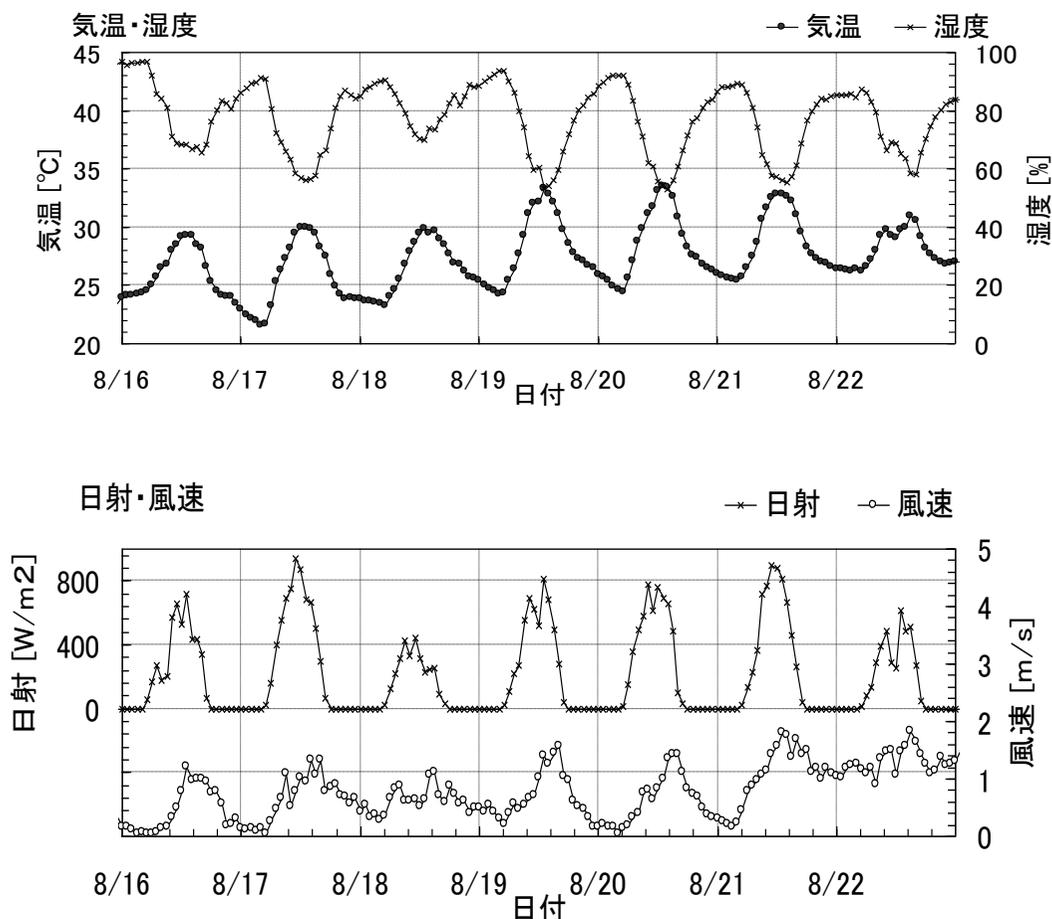


Fig.2 The general weather outlook during measurement periods (quantity of sunlight/ the wind velocity, temperature/ humidity)

In addition, the wind velocity ranged from 0 to 1.8m/sec, and wind direction was mainly south-west wind. South-west wind of 1.0m/s was recorded all day on

August 22. The humidity ranged from 56 to 97%, and the average humidity of the six days was 76.6% except August 16th when it was rainy. On August 21st, when the weather was stable all day, the surface temperature and MRT measurement result values are shown as follows.

3.2 Surface temperature

Changes over time of the surface temperature of the concrete wall surface and green panels on August 21 are shown in **Fig. 3**. The surface temperature of each wall was calculated by revising the measured long wavelength radiation according to the longwave

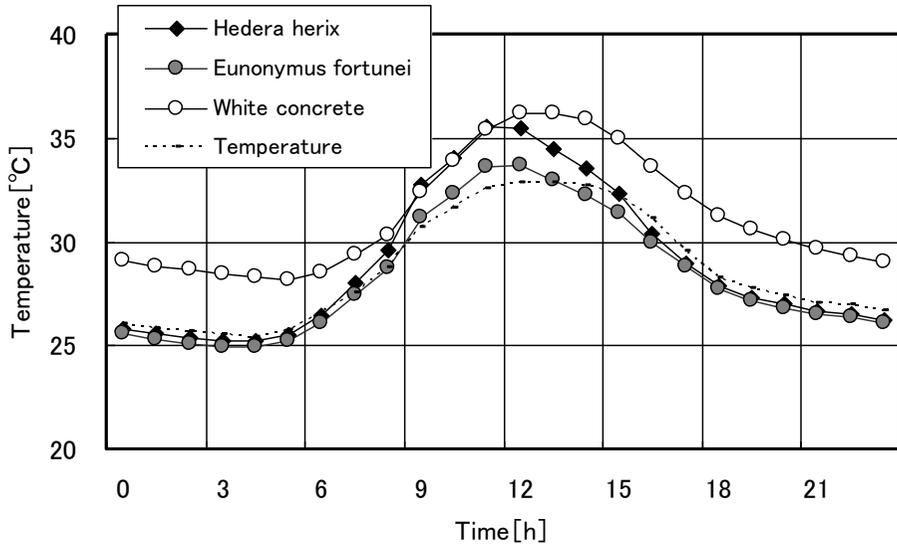


Fig. 3 Changes over time of surface temperature

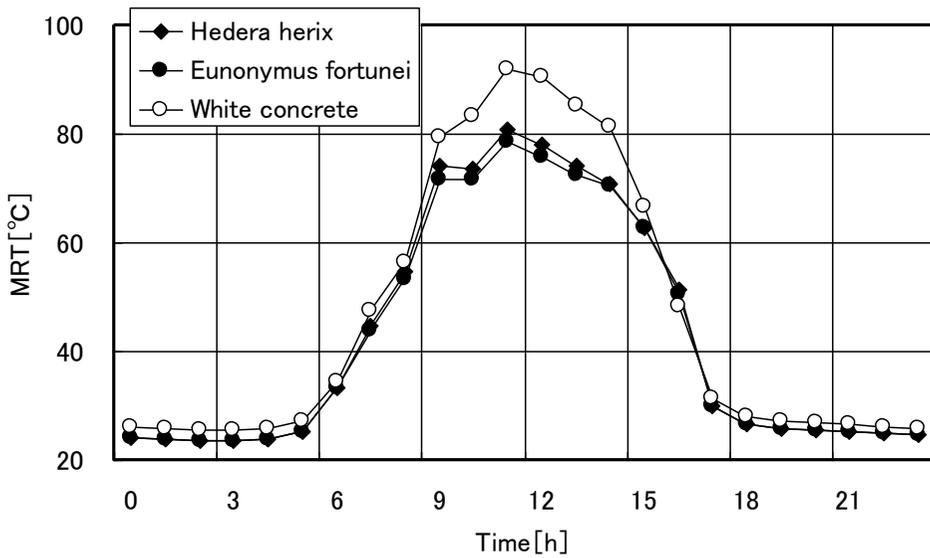


Fig. 4 Change over time of MRT

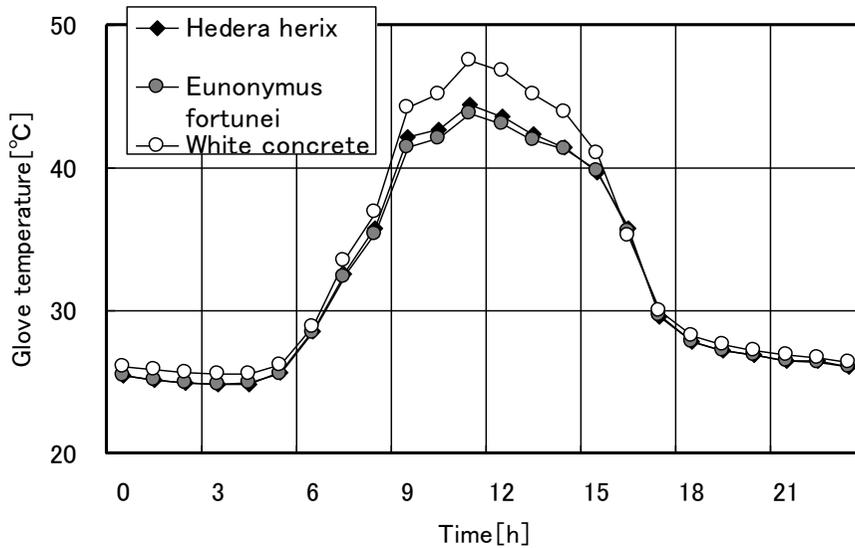


Fig. 5 Change over time of the glove thermometer

emittance. The surface temperature of *Hedera herix* was approximately the same as that of the concrete wall from 9:00 to 12:00, but that of the green panels fell 2 to 4 degrees lower than the concrete wall at other times. As a result of measuring the solar reflectance of the green panel materials, on the concrete wall, a high numerical value of 0.70 was recorded, while it was from 0.25 to 0.27 on the green panels.

Thus, the reasons why the difference between the surface temperature of green panels and the concrete wall narrowed at peak time is presumably not only that the leaf temperature increased but also that the rise of the surface temperature of the concrete wall was restricted because the concrete wall was painted white, reflecting sunlight. On the green panels, the surface temperature of *Eunonymus fortunei* was 1.8°C lower than that of *Hedera herix* at peak time, showing that the surface temperature of the plants used differs⁶⁾

3.3 Evaluation of the thermal environment improvement effect according to MRT (Mean Radiant Temperature)

Turning to the radiant environment, we verified the thermal environment improvement effects of wall greening based on MRT at a place relatively close to human living space. MRT (Mean Radiant Temperature) was one sensible indexes of the feeling of heat, and shows the average heat radiation coming from all surrounding directions⁷⁾. Specifically, using the blackball globe temperature (T_g),

dry-bulb temperature (T_d) of the globe thermometer and the supersonic anemometer (V), the MRT was calculated with Equation (2).

$$\text{MRT} = T_g + 2.37\sqrt{V} \times (T_g - T_d) \quad \dots \quad (2)$$

T_g : Blackball globe temperature [°C], T_d : Dry-bulb temperature [°C],

V : Wind velocity [m/s]

Changes over time in the calculation results for August 21 are shown in **Fig.4**. Thus, the temperature of the green panels was lower than that of the concrete wall all day. The difference between the temperature of the specimen and concrete wall increased as the temperature increased. At 11:00, the greatest peak time, *Hedera herix* was 80.9°C and *Eunonymus fortunei* was 78.5°C on the green panels, whereas on the concrete wall the temperature was 91.8 °C . The temperature of the green panels was from 11 to 13°C lower than on the concrete wall.

Almost no difference of the temperature between the different plants could be observed. And almost no difference between specimen temperatures could be observed at night. Changes over time of the globe temperature of green panels and of the concrete wall are shown in **Fig.5**. The MRT value was very high at 91.8°C, presumably because the globe thermometer showed 47.6°C, and the difference from the air temperature was 15.1°C. The temperature of the green panels remained lower than that of the concrete wall and the difference between them expanded as the temperature rose, showing that the MRT of the green panels fell to about 11°C lower at peak time than the temperature of the concrete wall.

The reason for these differences is presumably that because the concrete wall was painted white, it was effected more than the green panels by the difference of the albedo (solar reflectance). The thermal environment improving effects in outdoor spaces by wall greening can be estimated quantitatively using MRT as an index.

3.4 Results of measurements of quantity of transpiration by the weight method

3.4.1 Quantity of daytime evapotranspiration

The quantity of evapotranspiration was measured at 1 minute intervals by automatic measurement by placing one green panel unit of *Eunonymus fortunei*

on an electronic balance, treating the result as the quantity of evapotranspiration and calculating the quantity of evapotranspiration per unit 1m^2 from the area ratio.

The measured value of weight was taken as the moving 30 minute average, in order to average the scattered measurement values of the electronic balance results caused by the influence of the wind. The daily quantity of estimated evapotranspiration per day during the measurement period was calculated from the quantity of weight change in 24 hours from 0:00 until 24:00. Changes over time of the quantity of evapotranspiration in the daytime per unit (soil + plant) 1 m^2 is shown in **Fig. 6**.

The quantity of estimated evapotranspiration per day, based on measured results, is shown in **Table 2**. The highest value was recorded as $4,308\text{g}/\text{m}^2$ on August 19, as $4,015\text{g}/\text{m}^2$ on August 20, then it decreased gradually to $3,833\text{g}/\text{m}^2$ in August 21. The decrease of the quantity of evapotranspiration pattern corresponded approximately with the decreasing soil volume water content percentage pattern. The quantity of evapotranspiration per day for a three day period, two days after watering was an average of $4,052\text{g}/\text{m}^2$.

According to **Fig. 6**, it changed almost identically on each measured day, showing that the quantity of evapotranspiration tended to increase along with the increase of the temperature and intensity of solar radiation, the highest quantity of evapotranspiration value ranged from 457 to $576\text{g}/\text{m}^2 \cdot \text{h}$, when the temperature and intensity of solar radiation were at their highest values at 12:00, which was peak time.

3.4.2 Quantity of daily transpiration from plants

For two days, August 20 and 21st, one unit of the green panel specimens was covered by polyethylene and the quantity of transpiration from the *Eunonymus fortune* was calculated. The daily quantity of transpiration from the measurement results is shown in **Table 2**. It was recorded at $2,443\text{g}/\text{m}^2$ on August 20, $2,434\text{g}/\text{m}^2$ in August 21, and the two-day average was $2,438\text{g}/\text{m}^2$. The quantity of transpiration peak was recorded as $311\text{g}/\text{m}^2$ at 12:00 on August 20, as $392\text{g}/\text{m}^2$ at 14:00 on August 21, and the two-day average was $351\text{g}/\text{m}^2$. Thus, the quantity of transpiration from plants (*Eunonymus fortune*) was equivalent to about 60% of the quantity of evapotranspiration from panel materials.

3.4.3 Relationship of the latent heat flux with the net radiation quantity

Based on the quantity of evapotranspiration based on the measurement value by weight method, the latent heat flux was calculated by Eq. (1).

$$LE = L \times E$$

$$L = 2.5 \times 10^6 - 2400 \times \theta_a \dots (1)$$

LE : Latent heat flux [W/m^2] , L : Latent heat of vaporization [J/kg] , E : Evaporation velocity [$\text{kg}/\text{m}^2 \cdot \text{h}$] , θ_a : surface temperature [$^{\circ}\text{C}$]

The result is shown in **Table 3**. The integrating latent heat flux quantity per day was $9.70\text{MJ}/\text{m}^2$ on August 20th, and the highest value was $304.8\text{W}/\text{m}^2$ at 14:00, which was the peak time. Similarly, its quantity was $9.27\text{MJ}/\text{m}^2$ on August 21, and the highest value was $325.6\text{W}/\text{m}^2$ at 12:00, which was peak time. As the two-day average, the integrating latent heat flux quantity per day was $9.49\text{MJ}/\text{m}^2$, and the highest value was $315.2\text{W}/\text{m}^2$ at peak time.

In addition, regarding the latent heat flux by transpiration of the *Eunonymus fortunei*, the quantity of integration per day was $5.90\text{MJ}/\text{m}^2$ on August 20, and the highest value was $207.5\text{W}/\text{m}^2$ at 12:00, which was peak time. Similarly, its quantity was $5.88\text{MJ}/\text{m}^2$ on August 21, and the highest value was $262.3\text{W}/\text{m}^2$ at 14:00 as peak time.

As the two-day average, daily integrating latent heat flux quantity was $5.89\text{J}/\text{m}^2$, which occupied about 60% of the panel unit, and the highest value at peak time was $234.9\text{W}/\text{m}^2$, which occupied about 70% of the panel unit.

Then the thermal effects of latent heat flux were verified based on the relationship with the quantity of net radiation. The quantity of net radiation was calculated by Equation (2), based on the incidence emission quantity that was clarified from each value of the quantity of atmospheric radiation, surface radiation, incident solar radiation, and reflected solar radiation measured by a length wave radiometer.

$$Rn = (S_{\downarrow} - S_{\uparrow}) + (L_{\downarrow} - L_{\uparrow}) \dots (2)$$

Rn : Quantity of net radiation [W/m^2] , S_{\downarrow} : Quantity of incident solar radiation [W/m^2] , S_{\uparrow} : Quantity of reflected solar radiation [W/m^2] , L_{\downarrow} : Quantity of atmospheric radiation [W/m^2] , L_{\uparrow} : Quantity of surface radiation [W/m^2]

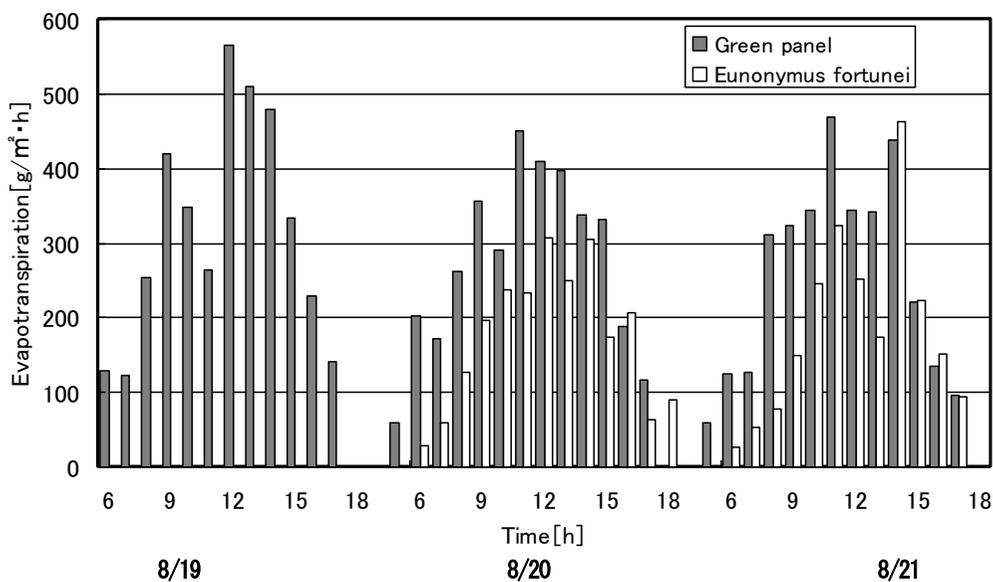


Fig.4 Changes of quantity of evapotranspiration (8/19-8/21)

Table 2 Result of measurements of quantity of evapotranspiration

Division	Item	August 19th	August 20th	August 21st	Average
A unit	Daily evapotranspiration	4,308	4,015	3,833	4,052
	[g/m ²]	576	457	487	507
	Peak time [g/m ²]				
A plant	Daily transpiration	-	2,443	2,434	2,438
	[g/m ²]				
	Peak time [g/m ²]	-	311	392	351
Daily transpiration / Daily evapotranspiration		-	0.61	0.64	0.60

Calculation results are shown in Table 3. In addition, changes over time of the latent heat flux and the quantity of net radiation are also shown in Fig.7. This

shows that the state of daily change of latent heat flux is similar to the quantity of net radiation. As the quantity of net radiation increased, latent heat fluxes also increased. Both increased in the peak hours from 12:00 till 14:00, after which they decreased.

As for the quantity of net radiation, it was recorded as less than $100\text{W}/\text{m}^2$ from 6:00 to 8:00 and from 16:00 to 18:00, and it decreased much less than the latent heat flux. It was thought that the transportation of heat as latent heat flux by evaporation from a unit continued until it exceeded the quantity of net radiation, whereas the quantity of shortwave solar radiation decreased suddenly in the hours when solar altitude was low.

The quantity of integrating net radiation per day was $7.65\text{MJ}/\text{m}^2$ on August 20, and the highest value was $326.3\text{W}/\text{m}^2$ at 13:00, which was peak time. Similarly, its quantity was $8.72\text{MJ}/\text{m}^2$ on August 21, and the highest value was $369.4\text{W}/\text{m}^2$ at 13:00, which was peak time. The two-day average of the daily quantity of integrating net radiation was $8.19\text{MJ}/\text{m}^2$ and the highest value was $347.9\text{W}/\text{m}^2$ at peak time.

The relation between the latent heat flux and quantity of net radiation is shown in **Fig.8**. In this study, more than $100\text{W}/\text{m}^2$ of net radiation for which evapotranspiration was relatively stable was treated as the object of our analysis. Equilateral correlation was confirmed between the latent heat flux and quantity of net radiation, and latent heat flux tended to rise as the quantity of net radiation rose. About 60% of the quantity of net radiation was used as latent heat flux on a unit panel, according to the degree of inclination of the regression line. Similarly, equilateral correlation was confirmed between the latent heat flux by transpiration of the *Eunonymus fortunei* and the quantity of net radiation, and about 50% of the quantity of net radiation was used as latent heat flux.

In these circumstances, it was suggested that the contribution by the quantity of transpiration of plants to the cumulative quantity of latent heat flux under the rise of net radiation was higher than that of the quantity of evaporation of the base soil. It can be said that as the percentage of the latent heat flux to the quantity of net radiation became higher, it restrained the rise of sensible heat flux outside of the building, contributing to improving the thermal environment. Therefore, it was also suggested that the latent heat flux by evapotranspiration accounted for most of quantity of net radiation, so that the sensible heat flux

reduction effects of the wall greening using green panels was large, and that in particular, the thermal effect of transpiration from plants was high.

Transpiration from plants occurred almost entirely through pores on the leaves' surfaces, and it is said that the quantity of transpiration in other ways than through pores was only about 5%⁸. When the water, which is discharged into the atmosphere by evapotranspiration from green panels, is changed from liquid to gas, latent heat is consumed. Latent heat could not cause a rise of the outside temperature, and as the quantity of evapotranspiration increased, latent heat fluxes continued to increase. This was expected to restrain the increase of the sensible heat flux which causes the heat island phenomenon. Kato⁹ reported that the average quantity of evapotranspiration per day was around 6.5mm, as a result of analyzing the relation between the quantity of evapotranspiration and soil water, intensity of solar radiation, installing containers made by plastic on the asphalt road surface, using lightweight soil and decomposed granite soil as compost, and using two kinds of plants of *Sedum mexicanium* and *Tifton grass*.

As a result of this measurement, the quantity of evapotranspiration per day by wall greening was 3.6mm by unit area. Compared with preceding studies, the measured value in this study are lower. It is assumed that a major reason for this is that the leaf area index of the plant used was 1.18, which is a comparatively small leaf quantity, and the water preservation condition of the compost was different because watering was not done during the period of measurement by weight.

On the other hand, regarding the relationship between latent heat flux and quantity of net radiation, the latent heat flux from green panels was kept to about 60% of the quantity of net radiation. As a result of the fact that we¹⁰ measured the quantity of transpiration by weight, using *Hedera Canariensis* which was planted in a planter in the past fiscal year, the latent heat flux accounted for about 25% of the quantity of net radiation, which is lower than 1/2 of this measurement result.

The plants used were different so the results cannot not be simply compared, and it was thought that the effectiveness of evapotranspiration rose higher when green panels were used than when planters were used, because of the integration of the plants and soil. The fact that the evapotranspiration differed greatly because of differences of soil condition suggests that the existence and incorporation of soil

Table 3 Latent heat flux and quantity of net radiation

Division	Item	Kind	August 20th	August 21st	Average
Latent heat flux [LE]	Integration per day [MJ/m ²]	(a) unit	9.70	9.27	9.49
		(b)plants	5.90	5.88	5.89
		(b)/(a)	0.61	0.63	0.62
	Peak time [W/m ²]	(a)unit	304.8	325.6	315.2
		(b)plants	207.5	262.3	234.9
		(b)/(a)	0.68	0.81	0.74
Quantity of net radiation [Rn]	Integration per day [MJ/m ²]		7.65	8.72	8.19
	Peak time [W/m ²]		326.3	369.4	347.9

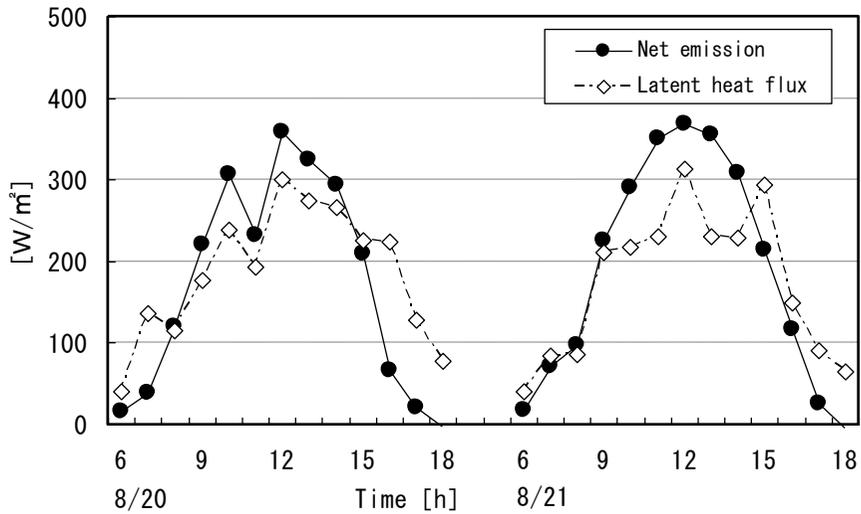


Fig.7 Changes over time in heat flux and net radiation

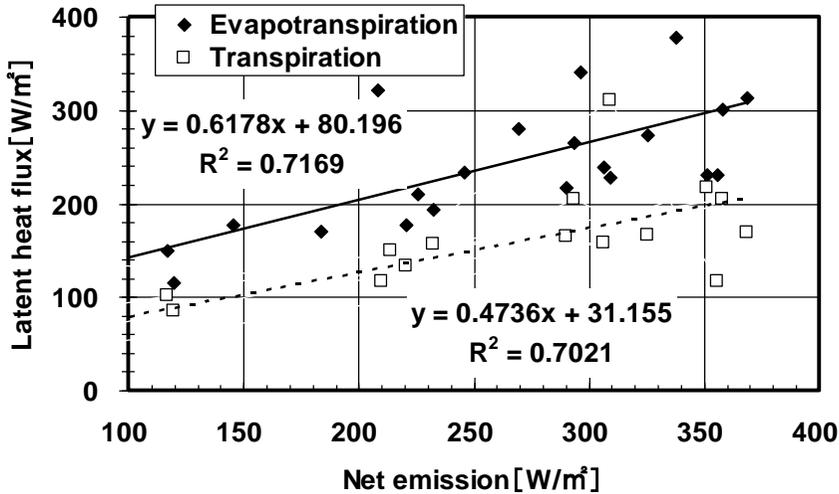


Fig.8 Relationship between latent heat flux and net radiation

integrated with plants contributes to effectively increasing the latent heat flux by wall greening.

Summary

We conducted experimental measurements using wall greening panels in order to quantitatively estimate how effectively wall greening improves the thermal environment outside of a building. The following are the major results of this study.

- ① The surface temperature of the green panels decreased around 2 to 4 °C below the temperature of the concrete wall at peak time in the daytime.
- ② As for the MRT, which was calculated from a measured blackball temperature value, the MRT of the green panels was about 11°C lower than that of the concrete wall at peak time.
- ③ The quantity of integrating evapotranspiration per day from a panel unit was about 4.1 kg/m² (≐4.1mm), the quantity of transpiration from plants was about 2.4 kg/m² (≐2.4mm), which accounted for about 60 % of the entire evapotranspiration from a unit.
- ④ Equilateral correlation was confirmed between the latent heat flux and the quantity of net radiation, and the percentage of the latent heat flux accompanying evapotranspiration of the quantity of net radiation was about 60%.

In the future, it will be necessary to estimate the of thermal environment improvement effects of greening the outside of a building to accumulate more basic data concerning the kinds plants, degree of coverage, differences between greening types and so on.

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IV. Greenery Space and Urban Environment

Study on actual states of public open spaces and the characteristics of green spaces constructed by Planned Development Design and Special Zoning Urban Area Systems in the 23 wards of Tokyo

Hiroataka Suzuki

Abstract: The objective of this study was to obtain fundamental data for creating green and open spaces in cities by investigating changes in public open spaces constructed by the Planned Development Design (P.D.D.)⁽¹⁾ and Special Zoning Urban Area Systems (S.Z.U.A.)⁽²⁾, and by surveying the actual states of such green spaces in the 23 wards of Tokyo. The study showed: 1) public open spaces could compensate for the lack of city parks in cities, 2) the total open space area was positively correlated with the area of the district, 3) there was no significant relationship between the areas of public open spaces and green-covered zones, and increases in open space area were not always accompanied by increases in the ratio of green coverage, and 4) the percentage of plaza type spaces was larger in the S.Z.U.A. system than in the P.D.D. system.

Keywords: public open space, greenery-covered ratio, planned development design, special zoning urban area

1. Background and Purpose of the Study

It is difficult to create greenery and open spaces by constructing public facilities such as city parks in the centers of large cities because the land is densely occupied by buildings. In the Planned Development Design System (hereinafter referred to as the “P.D.D. system”) and the Special Zoning Urban Area System (hereinafter referred to as the “S.Z.U.A. system”), conventional building regulations on floor area ratio and oblique

line can be relaxed when public open spaces and effective vacant land spaces are secured to encourage the creation of open spaces. In June 2004, the urban green conservation law was revised on urban greening, and the "greening area system" was established. This system prescribes the minimum greenery ratio in a building lot larger than a certain value. Roof-top greening is also prescribed under "regulations for natural protection and recovery" to promote greening in the center of Tokyo.

Many studies have been conducted on the public open spaces created by the P.D.D. system (public open spaces created by the P.D.D. system and effective vacant land created by the S.Z.U.A. system are referred to collectively as "public open spaces" in this study), including those on classifications of public open spaces¹⁾, the actual use and management of public open spaces²⁾, and systems and uses³⁾. However, there have been few studies on the relationship between public open spaces and green spaces.

These include a study by Nojima⁴⁾, which analyzed the correlation between the size of public open spaces and the number of trees and green coverage ratio; a study by Okamoto⁵⁾, which examined the relationship between public open spaces and greenery area in the center of Sapporo; and one by Kumano⁶⁾, which numerically calculated the relationship between public open spaces and the ratio of green coverage in the residential and commercial districts in the center of Osaka. There have been even fewer investigations about changes in public open spaces and the actual amount of greenery in the spaces with consideration of recent development trends, and there is little knowledge in this field. Therefore, this study aims to collect fundamental data about greenery and open spaces in city centers to analyze changes in the public open spaces that have been created by the S.Z.U.A. and P.D.D. systems, and to investigate the actual situation of green spaces in the 23 wards of Tokyo.

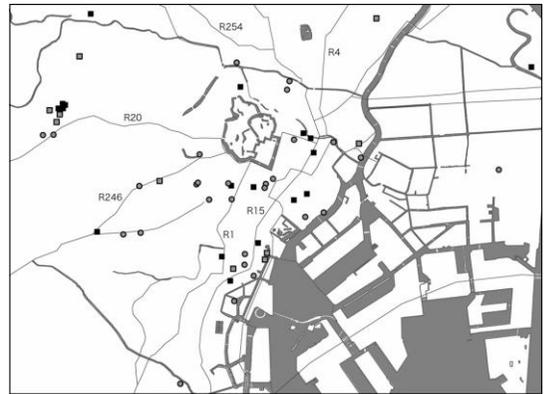
2. Methods

In this study, the relationship between blocks and public open spaces was investigated by 1) identifying block (site) areas and areas of public open spaces using available data of the S.Z.U.A. and P.D.D. systems in the 23 wards of Tokyo, and 2) drawing maps of the distribution of public open spaces and the analyzed distribution characteristics. 3) We also examined the relationship between the area of public open spaces and the ratio of green coverage in the three central wards of Tokyo (Chiyoda-ku, Chuo-ku, and Minato-ku) using the data of the time when city planning decisions were made for the S.Z.U.A. system projects. Investigation was conducted using data of the Tokyo Metropolitan Government⁷⁾ on 57 cases of the S.Z.U.A. system and 469 cases of the P.D.D. system.

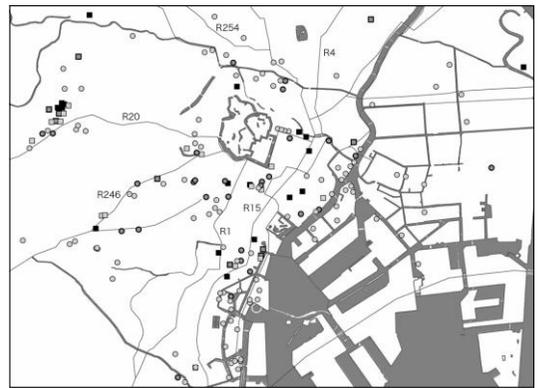
3. Characteristics of public open spaces in the 23 wards of Tokyo

According to documents of Tokyo^{7),8)}, as of March 2004, the S.Z.U.A. system has been applied to 60 districts (about 104 ha), and the P.D.D. system has been

1985



1995



2002

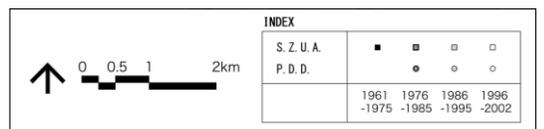
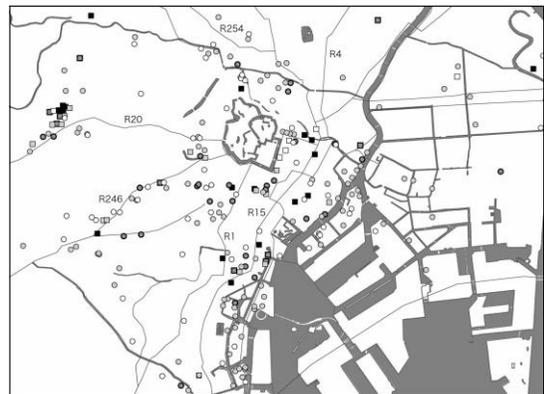


Fig.1 Sites of Application of the Planned Development Designe and Special Zoning Urban Area Systems

Table1 Areas of city parks and public open spaces

	(A)PublicOpen Space		(B)Public Park	(A)/(B)
	P.D.D.	S.Z.U.A.		
3wards	56.0ha		187.7ha	0.42
23wards	133.3ha	53.8ha	3,267.3ha	0.06

P.D.D.: the Planned Development Design

S.Z.U.A.: Special Zoning Urban Area

applied to 506 cases (about 347 ha). Compared with the S.Z.U.A. system, which needs city planning decisions, the P.D.D. system is widely used since no city planning decision is required; the system can be implemented only with the permission of the relevant administrative agency.

3.1 Analysis of distribution characteristics of public open spaces

We set 1976, when the P.D.D. system was founded, as the reference year, and classified years after 1976 in units of 10 years. **Fig.1** shows spaces constructed by the systems in the 23 wards of Tokyo in 1985, 1995, and 2002.

3.1.1 Special Zoning Urban Area System

The S.Z.U.A. system was applied to 10 cases from 1961, when the S.Z.U.A. system was founded, to 1975. It was applied to 20 cases every 10 years thereafter. The first application was redevelopment of the former Yodobashi Water Purification plant in Nishi-Shinjuku into a site consisting of 20 skyscrapers including the building of the Tokyo Metropolitan Government. From 1976 to 1985, the Special Zoning Urban Area has been applied to areas along wide roads, such as Aoyama Street, and blocks near Hibiya Park. From 1986 to 1995, it was applied in another district in Nishishinjuku. Since 1996, it was applied to large blocks in Yuraku-cho.

3.1.2 Planned Development Design System

The P.D.D. system was applied to 54 cases in the 10 years from 1976 to 1985, and to 294 cases in the 10 years after 1986, showing a sharp increase. From 1976 to 1985, the system was implemented mainly in

districts near the Imperial Palace in the center of Tokyo, such as Hibiya, Toranomom, Akasaka, and Ochanomizu. In the 10 years from 1986 to 1996, the system was increasingly applied in areas along Tokyo Bay and involved the construction of large-scale commercial buildings and multi-story condominiums, such as Mitsui Warehouse Hakozaki Building, Okawabata River City, and Tennozu Isle to use the land plots occupied by distribution warehouses in Shibaura, Konan, Tennozu, and the river mouth of Sumida River for other purposes.

At the same time, public open spaces with greenery gardens were constructed, such as those near Toranomom Tower and Shiroyama Hills Buildings in Toranomom. In these cases, commercial institutions and condominiums were integrated. The integration of two or more adjacent land lots has enabled large-scale open spaces to be created. Since 1996, 20 years after its foundation, the system was used to create a continuous public open space along the sidewalk of Aoyama Street by setting back walls, and to redevelop a center block in Iidacho, where the former Iidacho Station and some offices were located, into an area consisting of commercial institutions and multi-story condominiums.

3.1.3 Relationship between public open spaces and public parks

The total area of public parks, which was calculated by adding city parks and coastal parks, and the areas of public open spaces constructed by the P.D.D. system and the S.Z.U.A. system in the 23 wards and the three central wards (Chiyoda-ku, Chuo-ku, and Minato-ku) of Tokyo are shown in Table 1 based on the records of the Tokyo Metropolitan Government⁹⁾. In the 23 wards, public parks occupied 3,267.3 ha, and public open spaces of the P.D.D. and S.Z.U.A. systems occupied 187 ha, which is equivalent to about 6% of the area of the public parks. On the other hand, in the 3 wards (Chiyoda-ku, Chuo-ku, and Minato-ku), public open spaces occupied 78.6 ha, which is equivalent to about 42% of the park area. Public open spaces constructed by the P.D.D. and S.Z.U.A. systems thus appear to be compensating for the lack of city parks in the center of Tokyo.

3.2 Relationship between public open spaces and green spaces

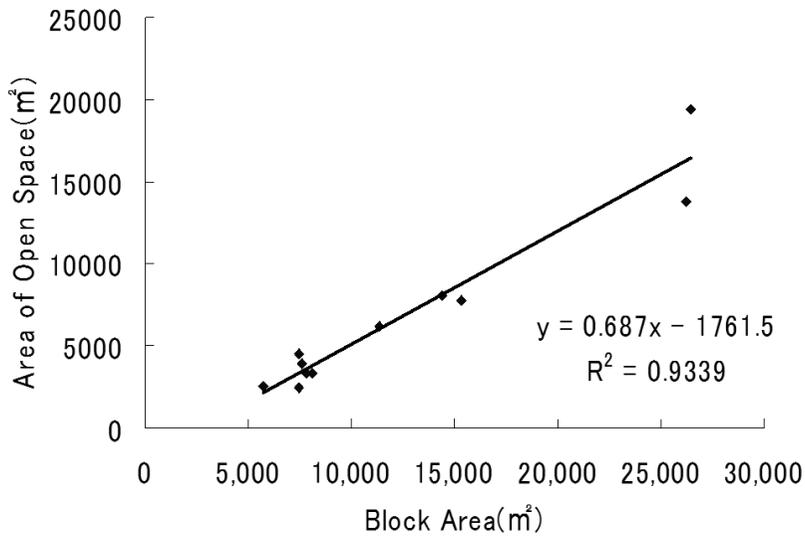


Fig.2 Relationship between areas of blocks and public open spaces (Special Zoning Urban Area)

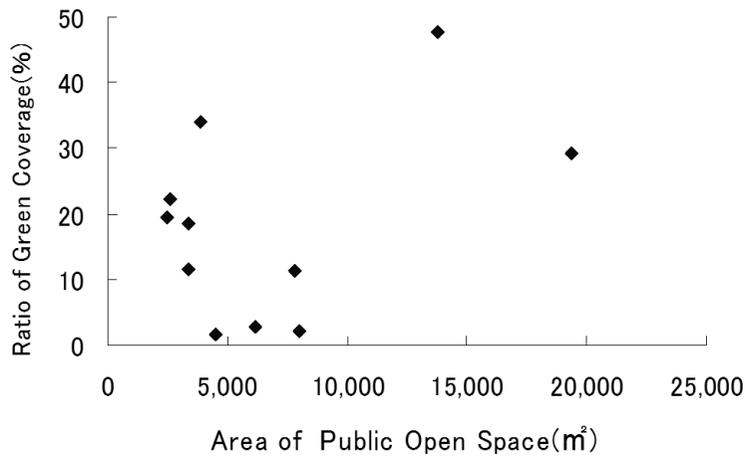


Fig.3 Relationship between area of public open spaces and ratio of green coverage (Special Zoning Urban Area)

The authors investigated the relationship between public open spaces and green spaces constructed in the three central wards of Tokyo by the two systems. The results are described in the rest of this section.

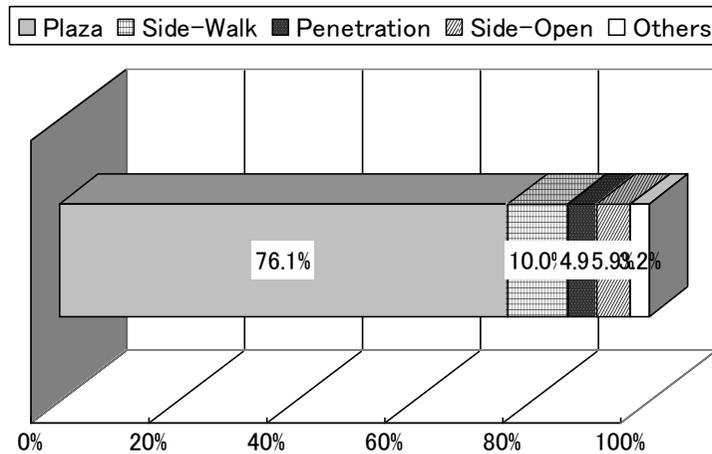


Fig.4 Percentage of each type of public open space in Special Zoning Urban Area Districts

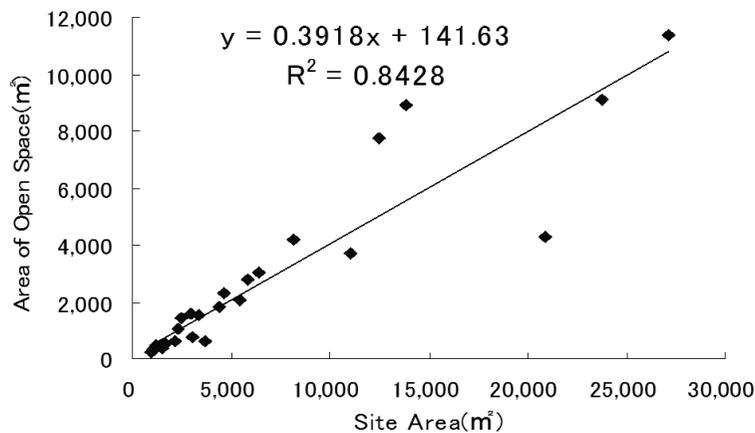


Fig-5 Relationship between site area and public open space area (the Planned Development Design)

green spaces constructed in the three central wards of Tokyo by the two systems. The results are described in the rest of this section.

3.2.1 Special Zoning Urban Area

(1) Public open spaces and ratio of green coverage was under 10,000 m², and 20 to 50% when the area was over 10,000 m². According to documents

of the Tokyo Metropolitan Government⁷⁾, the S.Z.U.A. system has been applied to 27 cases in the three central wards of Tokyo. The green cover areas could be calculated for 11 of those cases by preparing greenery maps based on drawings and supplementary field surveys. As shown in **Fig.2**, a positive correlation was found between the block area and the area of public open spaces, and the larger the block area, the larger the area of public open spaces. In contrast, as shown in **Fig.3**, no significant relationship was observed between the area of public open spaces and ratio of green coverage. However, the ratio of green coverage tended to be in the range of 0 to 20% when the area of public open spaces

(2) Characteristics for each type of public open space

According to the standards¹⁰⁾ of the Tokyo Metropolitan Government, public open spaces are classified into the "blue sky type (plazas and gardens)", the "side opening type (pilotis and arcades)", the "indoor plaza type", and the "concourse type". These public open spaces also include "sidewalk-shaped open spaces" and "penetration passage". A sidewalk-shaped open space is an open space along a sidewalk with no grade difference and is used as a continuous space with the sidewalk.

A penetration passage is an open space constructed in a lot as a passage for walkers connecting a road and a park. We classified sidewalk-shaped open spaces and penetration passages as independent types of the "sidewalk type" and the "penetration passage type". The other outdoor spaces were classified into three: the "plaza type", the "side opening type", and "others", which included the indoor plaza type and concourse type. The areas of each type of open spaces were calculated based on references of the Tokyo Metropolitan Government, and the results are shown in **Fig. 4**. As shown in the figure, the "plaza type" accounted for more than 70% (76.1%) of all open spaces, followed by the "sidewalk type" (10%) and the "side opening type" (5.9%) in this order.

3.3.2 Planned Development Design

(1) Public open spaces and ratio of green coverage

According to documents of the Tokyo Metropolitan Government⁸⁾, the P.D.D. system has been implemented in 247 cases in the three central wards of Tokyo, accounting for about 50% of all cases applied in the 23

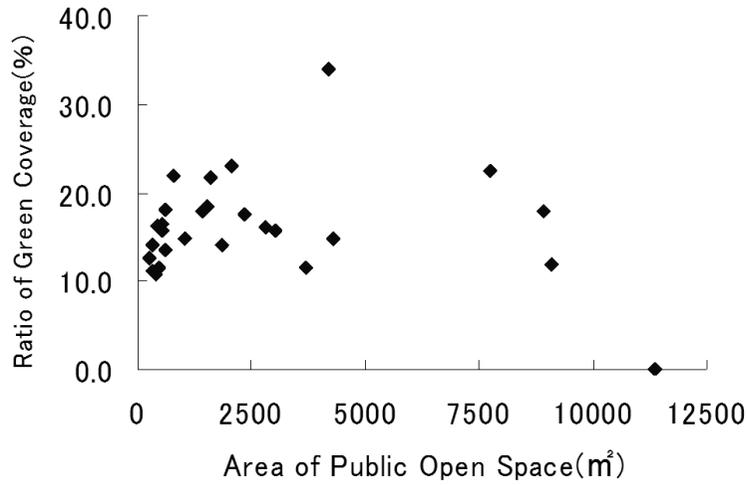


Fig-6 Relationship between area of public open spaces and ratio of green coverage (Planned Development Design)

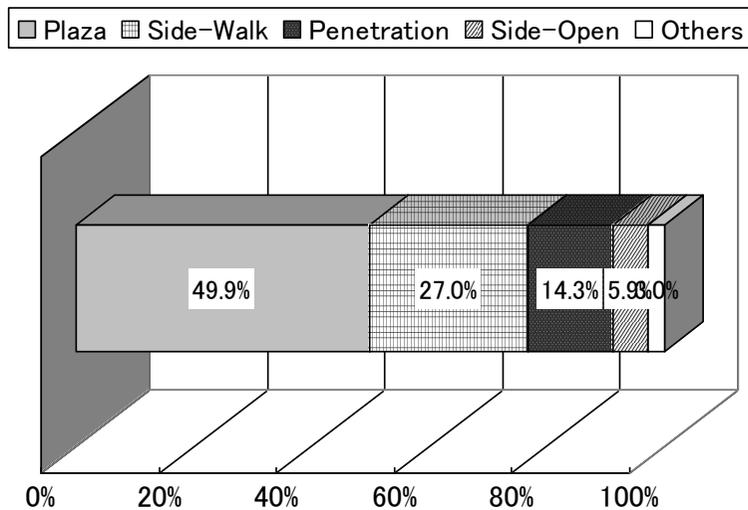


Fig-7 Percentage of each type of public open space in Planned Development design sites

wards. In this study, we extracted 27 out of 93 cases in which green covered areas were determined in documents for building inspection approval of the

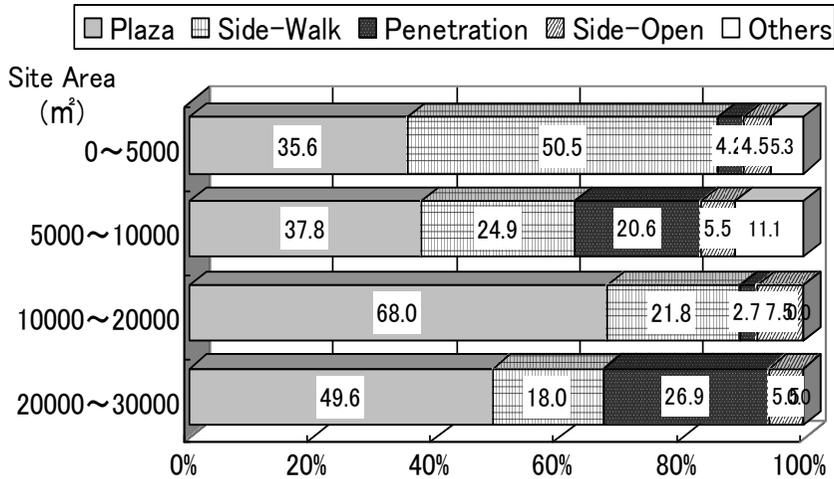


Fig.8 Sizes of public open spaces and percentage of open space type in Planned Development Design districts

Tokyo Metropolitan Government, and examined the relationship between public open spaces and green spaces. As shown in **Fig.5**, there was a close correlation between site area and the area of public open spaces. The areas of public open spaces were larger in larger sites. The relationship between the area of public open spaces and the ratio of green coverage is shown in **Fig.6**. No significant correlation was found between them, and increases in the area of public open spaces were not always accompanied by increases in the ratio of green coverage. This finding should be considered when constructing green space systems in cities. :

(2) Characteristics of public open space by type

We classified public open spaces into five types based on a summary report of the Tokyo Metropolitan Government¹¹⁾: 1) the plaza type, the sidewalk type, the penetration passage type, the side opening type, in which pilotis are included, and the other type. Areas for each type are shown in **Fig.7**. The "plaza type" accounted for the largest percentage, 49.9%, of the total open space area, followed by the "sidewalk type" (27.0%), and the "penetration passage type" (14.3%) in this order. Compared with those constructed by the S.Z.U.A. system, the percentage of the "plaza

type" was small, and the "sidewalk type" and the "penetration passage type" accounted for large percentages.

This was probably because the S.Z.U.A. system is frequently used in districts consisting of two or more building lots where open spaces do not need to be constructed among the lots because there are roads, but the P.D.D. system is usually applied to single lots, requiring open spaces to be constructed in the lots to serve as roads and paths connecting buildings. The percentages of the five types of open space are shown in **Fig.8** for each lot size. In lots smaller than 5,000 m², about 50% of open space was the "sidewalk type". In lots of 5,000 to 10,000 m², the "plaza type" accounted for 40%, and in lots of 10,000 to 20,000 m², the "plaza type" accounted for as much as 70%. In lots larger than 20,000 m², the ratio of the "plaza type" decreased to about 50%, but the percentage of the "penetration type" increased to about 26%.

Summary

In this study, we investigated changes in application of the S.Z.U.A. and the P.D.D. systems for constructing public open spaces, and surveyed the actual states of public open spaces and green spaces in the 23 wards of Tokyo. As a result, the following conclusions were drawn: ① In the three central wards of Tokyo, public open spaces accounted for about 40% of the area of public parks, compensating for the lack of green spaces, suggesting the difficulty of constructing public green spaces such as city parks in the center of cities and the large potential of creating green spaces in large privately owned land. ② There was a close correlation between block/site scale and the area of public open spaces, but no significant correlation was observed between the area of public open spaces and the ratio of green coverage. This was probably because the ratio of green coverage was uniformly calculated based on block and site areas, but open spaces vary in functions and greenery characteristics depending on types, such as plaza, sidewalk and passage. ③ The "plaza type" accounted for about 70% of public open spaces in districts where the S.Z.U.A. system was applied, whereas the percentage of the "plaza type" was small, and the percentage of the "sidewalk type/penetration passage type" was large in districts constructed by the

P.D.D. system, probably because the former is applied in units of blocks consisting of two or more building lots whereas the latter is applied in units of lots.

The Urban Green Law, which was enacted in June 2004, requires "greening areas" to be decided in city planning and at least a certain percentage of green covered area to be constructed in lots larger than a certain size. Implementation of the law and the P.D.D. and S.Z.U.A. systems for constructing open spaces will promote the creation of green spaces in large building lots. We need to accumulate basic data on open spaces in large privately owned land and their greening states.

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Notes

(1) The Planned Development Design System encourages the creation of open spaces by relaxing conventional building regulations on floor area ratio and oblique line when public open spaces and effective vacant land spaces are secured and other requirements are met.

(2) The Special Zoning Urban System sets zones where the maximum heights of buildings, floor area ratio, and wall surface position limits are to be decided by city planning, and general regulations of the Building Standard Law of Japan are not applied. Regulations on floor area ratio can be relaxed when sufficient vacant land spaces are secured.

(3) "Block area" denotes the area of a "block", which is a development unit of the Special Zoning Urban Area System, and "site area" denotes the area of a "site", which is a development unit of the Planned Development Design System.

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V. Biodiversity Science

A Field Note: Fruit-Bearing Birds: White Eyes as Pollen Vectors of *Camellia japonica*²

Yoko Kunitake (translated by A. Taki)

1. Pollinators' Role in the Evolution of Flowers

Plants, as the lack of animal free locomotion is their gift, let someone else mediate their intra-specific gene flow. Such a trading of pollens is called pollination whereas plants mediated by animals in their pollen-trading are called animal-mediated plants. Animals such as insects and birds come and search a plant for their food such as nectar and pollen but some of them chance to play the role of a trader of pollens. Without those pollinators, plants cannot reproduce themselves. This botanical sacrament is, as shown in some cultivation methods of agricultural products, immeasurably important for our life as the foundation of the agricultural food supply. Farmers cultivating strawberries and tomatoes, for example, when the plants begin to bloom, let artificially fostered bumblebees go off in the greenhouse, in order to arrange that the bees trade pollens.

Animal-mediated plants are making a variety of appeals, whether with eye-catching petals or by emitting an odour, by which means to attract pollinating insects and birds. One of the evolutionary interests researchers have favoured is that the characteristics of a plant such as the shape and colour of the flower, the time of flowering and the number of simultaneously blooming flowers are correlated to its interaction with its pollinators. Many studies have focused on this interesting correlation.

How a flower has evolved cannot fully be described unless its pollinators are specified. All of the visitors to the flower are not its pollinators. Some visitors just

² 国武陽子「果実を実らせる鳥—メジロはヤブツバキの花粉媒介者だった」, Y. Kunitake (2002) '*Kajitu wo Minoraseru Tori: Mejiro wa Yabutsubaki no Kafun-Baikai-Sha datta*' *Dobutsu to Dobutsuen*, 626, 10-12. For her academically more careful discussion with accurate experiment method and statistics, see Y. Kunitake, M. Hasegawa, T. Yamashita, and H. Higuchi (2004), 'Role of a seasonally specialist bird *Zosterops japonica* on pollen transfer and reproductive success of *Camellia japonica* in a temperate area' *Plant Species Biology*, 19, 197-201.

eat its nectar and pollens, not contributing anything to trading its genes. Since nectar and pollens are, taken in a flower's terms, limited resources for reproduction, it is favourable to invite the pollinators to frequent the flower, preventing useless visitors from consuming the resources. The priority is not the variety of visitors but the number and frequency of effective visitors. The first step to discuss the flower-animal interaction, therefore, is to distinguish, among the visitors to the flower, those effective for pollination from those which eat and go. Look at wild flowers sometime and you will find various animals come and go but behind the peaceful pastoral scene there might be a severe struggle for reproduction going on at the moment.

2. A Line-up of Pollinators

Who are the pollinators? Among the flower visiting animals the most popular will be butterflies, bees and some other insects. As can be expected, a good number of plants are pollinated by insects, among which are counted a wide range of insects, including beetles, diptera such as flies and gadflies, hymenoptera such as bees and ants, lepidoptera such as butterflies and moths. However, there are more plants than expected which are pollinated by birds and mammals. In the tropical region a number of plants are pollinated by birds and bats. The case that a flower pollinated by a hummingbird corresponds in form to its beak is, in particular, well-known as a case of co-evolution.

For people living in the latitude of temperate climate like the Japanese, insects are no doubt counted first. In those zones of the globe, insects are, in fact, the pollinators of most of the animal-mediated plants. Since most of the plants there begin to bloom from spring to the beginning of autumn, animals if their nutrition were only a flower's nectar, could not have anything to eat in winter. In autumn, flower visiting insects in a temperate area die or stop their activities. In contrast, most birds and mammals, warm-blooded animals, since they are active throughout the year, tend to evolve, if they inhabit in a temperate area, toward utilizing nectar as main nutrition and correspondently, plants there will have more chances of utilizing those birds and mammals as their pollinators. That is what researchers have hypothesised as the reason that the pollination by birds and mammals is observed mostly in the tropic and sub-tropic zones.

3. A Pollinating Bird in a Temperate Area

However, Japanese people can observe in their daily life a very rare case of a bird pollinating in a temperate area. It is a nightingale-coloured, that is, olive brown, small bird with the white around the eyes, the one they can observe in their garden throughout the year. White eyes! That's it. There is now a good reason to conjecture that Japanese people in the past mistakenly chose for the main topic of their poems a white-eye as a nightingale, which corroborates the assumption that the colour named "nightingale colour" looked more akin to the feather colour of white-eyes than to that of nightingales.

White-eyes can be observed to frequent a flower of *Camellia japonica* in Japanese gardens in winter. A camellia blooms a flower at the end of its branch but a white-eye, hanging on a thin twig or leaf as adroitly as if an acrobat, sucks nectar by thrusting its whole head into the centre of the flower. You may see the white-eye finishing the suck and raising the head with a ring of yellow pollens around the beak. It will look smile-provokingly lovely.

White-eyes do not choose flower nectar as nutrition all the year. According to the field observations on their yearly food variety I conducted in Niijima Island, the Izu Islands, Japan, they consume animal nutrition such as lepidoptera's larvae and spiders from spring as their reproductive season until summer; and in autumn they frequently consume in addition fruits such as berries of mock orange, *Eurya japonica* and *Callicarpa japonica*. Around that time there is a wide variety of food. However, when *C.japonica* begin to bloom, white-eyes bit by bit more frequently consume their nectar. In January and February 70 to 85 percentage of consumption is the flower nectar of camellia. The observations revealed that although the yearly nutrition resources vary white-eyes very much depend on camellia's flower nectar in winter, the season when *C.japonica* bloom.

From these findings my research team hypothesised that if white-eyes in a temperate area, which consume flower nectar only in winter, pollinated the *C.japonica* as they bloom in that season, it would be the case of a warm-blooded animal's pollination in a temperate area and in addition, that white-eyes' nutrition consuming behaviour can be different from that of tropical birds feeding on flower nectar throughout the year and that there is some interaction in evolution between white-eyes and *C.japonica*. Our research interest focussed on the interrelation of

white-eyes with *C.japonica*.

4. Are White-Eyes Pollinators of *C.japonica*?

Even if camelliae are primary nutrition resources for white-eyes in winter, are white-eyes in truth effective pollinators for *C.japonica*? Among the animals visiting camellia's flowers, which contributes to pollination, we observed in the following experiment.

There are mainly two kinds of visitors to camellia's flowers: small-bodied arthropods such as bees, ants and spiders and birds such as brown-eared bulbuls and white-eyes. We devised a bag so tenuously meshed as to prevent all preliminarily identified visitors having access to camellia's flowers. We also devised a cage with its grids so loose as to allow insects and spiders in but to keep white-eyes out. With these devices we arranged three types of camellia flower: one covered with the meshed bag, another covered with the cage and the third with no cover, that is, open to any visitor. Under these three conditions we observed on which condition flowers would bear fruit.

As a result of this experiment, the first type bore no fruit, the second open only to the insects bore almost no fruit and the third open to any with an overwhelming frequency bore fruit. In consequence we were in a position to conclude reasonably that camellia's main pollinators are birds, not insects.

Then, are both brown-eared bulbuls and white-eyes camellia's pollinators? Brown-eared bulbuls are certainly observed to visit *C.japonica* but the flowers they have visited are often observed to be deprived of their important reproductive organs such as the stigma and the anther. Since their visitation frequency is lower than white-eyes', it will be a favourable hypothesis that they are not camellia's pollinators but rather animals doing the damage to its flowers by consumption.

5. Camellia's Characteristics Attractive to White-Eyes

C.japonica have large red petals and secrete voluminous highly sugared nectar from the base of the flower centre. These characteristics agree with the flowers raising bird-mediated pollination. In general, birds' colour vision is known to be sensitive to red. When we compared in the white-eyes' visitation frequency

the flowers without any modification with the flowers painted white in a spray-canned paint, there was almost no difference observed but the artificially white painted flower gathered numerous insects such as flies. Perhaps, red flowers are not only eye-catching for birds but also exclusive for insects as comparatively unmarked signals. The volume of nectar camellia's flowers secrete varies among individual flowers and *C.japonica*. It is reported that hummingbirds' visitation frequency is proportion to the volume of nectar the inflorescence secretes, but such is not the case with white-eyes. White-eyes' visitation frequency turned out to be proportional to the number of the flowers a tree blooms.

6. Conclusion

In terms of inter-special interaction, a plant and a bird very familiar to the Japanese people like a camellia and a white-eye have made a very interesting case for the pollination by a warm-blooded animal in a temperate area. These findings seem to me to suggest that familiar living organisms in our daily life, familiar landscapes and our very common environment can be very valuable in truth. Some living organisms, such as *medaka*, Japanese killifish, which used to be common have been rare species now. The noble orchid or the *Cephalanthera erecta* were not rare just ten years ago. Pastoral landscapes spreading in the rural hilly area adjacent to the human resident area used to be representative landscapes in Japan. Things commonly seen in the past, beaches for shell gathering at low tide or foxes' nesting caves, are being lost.

Living organisms in nature and the environment certainly have immeasurable values. These values can be recognised not by considering whether or not a species or the environment exists or whether there are many or few individuals of a species but by observing how living organisms inhabit in their proper habitats or in the environment and how they function there. It is no doubt important to take protective measures toward the species that have already become rare but none the less important it is to observe carefully the species still commonly seen. My wish is to keep hold of the sensibility of being moved when one has recognised how valuable nature is as the familiar and common background.

Only with this sensibility will we be able, I believe, to stop our ignorance and indifference from losing any more valuable things before we know it.

VI. Horticulture and Society

Actual Conditions and Problems Regarding the Preservation and Ongoing Survival of Traditional Horticultural Plants in Japan

Hiroataka Suzuki

Abstract: Japanese traditional horticultural plants rose to prominence during the Edo era and a unique horticultural culture was formed comprising new cultivars, cultivation techniques, and an appreciation of plants in general. However, since the Meiji Restoration, which ended the Edo era, the Japanese people's attitude toward horticulture has changed and the popularization of gardening and other such pursuits has meant that traditional horticultural plants have not always been adequately preserved and that some cultivars are now extinct. This research project sought to collate the fundamental data needed in order to preserve and ensure the ongoing survival of traditional horticultural plants by carrying out a questionnaire survey of the main botanical gardens in Japan and other such groups involved in their preservation. As a result, it was found that only about 30 % of the 67 botanical gardens surveyed have preserved traditional horticultural plants in their collections, and that many of these plants were only being maintained because they were flowering varieties. On the other hand, while the preservation groups surveyed were found to have maintained many different cultivars in their collections, 8 species of plant had not been adequately maintained and are now threatened with extinction. We conclude that it is necessary to have access to successful cultivation techniques, to properly define and register cultivars and to establish a unified organization for cultivar definition and registration in order to ensure their preservation and ongoing survival.

Keywords: traditional horticultural plants, horticultural culture, preservation and ongoing survival, cultivar definition

1. Backgrounds and Purpose

This horticultural culture was especially prominent among the samurai class and the common people during the Edo Period, when a policy of deliberate isolation resulted in a peaceful age, free from war, which continued for 260 years.

In the cultural climate created by this historical social environment, new horticultural forms were created such as plants with exceptional or unusual leaf color, and superior kinds of plants which were then ranked like 'Banzuke' or compiled into plant lists called 'Catalog' or 'Illustrated Book'. However, many of the traditional horticultural plants which were originally developed as part of this horticultural culture in Japan have since fallen into neglect, though some are still maintained and preserved by plant enthusiast groups. Mori¹⁾ pointed out that a problem with preservation and ongoing survival is that variety names have not been recognized internationally. Ogisu²⁾ used the term, traditional horticultural plants, as a term including cultural value, compared with classic horticultural plants³⁾. Concerning traditional horticultural plants, lovers and private groups have independently possessed and preserved these for successive generations⁴⁾.

Now, because of the increasing age of many of the members of these groups, some species of horticultural plant now face the risk of extinction unless action is taken to preserve them. Although each of these groups have successfully helped to preserve and ensure the survival of many plant species until now, not all the relevant data have been comprehensively arranged so that it is readily accessible for all. On the other hand, in those Japanese botanical gardens which have also been involved in plant preservation and the exhibition of plant species in Japan, in either a public or private capacity, the actual conditions under which traditional horticultural plants have been maintained and the role these organizations are taking in further preservation and exhibition is not always clear.

This research project sought to clarify the current conditions and problems, based on the questionnaire, regarding the status of those traditional horticultural plants held by the relevant organizations and concerned groups throughout Japan, in order to ensure their preservation and ongoing survival.

2. Methods

As for organizations, we chose 137 organizations, all of which are members of the Japan Association of Botanical Gardens. Concerning the groups, from existing documents, first we selected plants which are traditional horticultural plants, then, through the internet, we obtained information about the preservation activities of these groups or hobby clubs concerning every plant item. Individuals and trade

groups were eliminated from the objects of this research. The questionnaire had been carried out during 21 days, since March 3rd till 24th in 2009. In response, 67 replies were received (an effective response rate of 48%) from organizations such as botanical gardens and 26 replies were received (an effective response rate of 53%) from preservation groups, giving a total of 93 replies (an effective response rate of 93 %, overall).

3. Definition and scope of the traditional horticultural plants investigated

3.1 Definition of traditional horticultural plants

In order to ensure the preservation and ongoing survival of ‘traditional horticultural plants’, it is first necessary to produce a clear definition of this term, the wording ‘traditional horticultural plants’ to describe the style of horticulture characterized by beauty, an appeal to the senses, intelligence and craftsmanship in the Edo era. In this report, we have adopted the wording ‘traditional horticultural plants’, as proposed by Ogisu et al.¹⁾, and have defined ‘traditional horticultural plants’ as following conditions:

- (Condition-1) Ornamental plants raised during the Edo Period, reflecting the unique aesthetic sense and values of the Japanese people
- (Condition-2) Cultivars that required considerable time and effort to develop, and whose ornamental appearance now bears hardly any resemblance to those of the original wild species
- (Condition-3) Plants from which a large number of varieties have subsequently been developed and whose variety names are firmly based in Japanese culture
- (Condition-4) Cultivars that have been developed in Japan and can be raised in Japan's climate and soil, regardless of whether they were originally native or introduced species

Based on this definition, Categories and Japanese Names of Japanese Traditional Cultivars are shown in **Table 1**.

Table 1 Names of Japanese Traditional Cultivars

Categories	Japanese Names (<i>Scientific name</i>)
Trees	Hana-ume(<i>Prunus mume Sieb. et Zucc.</i>), Boke(<i>Chaenomeles Lindl.</i>), Sakura(<i>Prunus L.</i>), Hana-momo(<i>Prunus persica (L.) Batsch</i>), Kaede(<i>Acer L.</i>), Tsubaki · Sazanka(<i>Camellia L.</i>), Tsutsuji · Satsuki(<i>Rhododendron L. nom cons</i>), Fuji(<i>Wisteria Nutt.</i>), Botan(<i>Paeonia L.</i>), Karatatibana(<i>Ardisia crispa (Thunb.) DC.</i>), Yabukoji.(<i>Ardisia japonica (Thunb.) Blume</i>), Manryo(<i>Ardisia crenata sims</i>), Nanten(<i>Nandina domestica Thunb.</i>), Hanazakuro(<i>Punica granatum L.</i>), Matsu(<i>Pinus L.</i>), Sugi(<i>Cryptomeria japonica (L.f.)D. Don</i>)
Grasses	Asagao(<i>Pharbitis nil (L.) Choisy</i>), Omoto(<i>Rohdea japonica (Thunb.) Roth</i>), Hana-syobu(<i>Iris ensata Thunb.</i>), Kakitsubata (<i>Iris laevigata Fisch.</i>), Kiku(<i>Dendranthema (Desmoul.)Kitam.</i>), Sakuraso(<i>Primula sieboldii E. Morr.</i>), Shakuyaku(<i>Paeonia lactiflora Pall.</i>), Ise-nadeshiko(<i>Dianthus isensis</i>), Fukujuso(<i>Adonis amurensis Regel et Radde</i>), Saishin(<i>Asarum L.</i>), Ha-Ran(<i>Aspidistra elatior Blume</i>), Sekisyo(<i>Acorus gramineus Soland.</i>), Tsuwabuki(<i>Farfugium Lindl.</i>), Yukiwariso(<i>Hepatica nobilis Mill.</i>), Kunsi-Ran(<i>Clivia miniata Regel</i>), Mon-tenjiku-aoi(<i>Pelargonium zonale (L.) L'Her.ex.Ait</i>)
Orchids	Fuki-Ran(<i>Neofinetia falcate (Thunb.) H. H. Hu</i>), Chosei-Ran(<i>Dendrobium moniliforme (L.)Swartz</i>), Syun-Ran(<i>Cymbidium goeringii (Rchb.f.)Rchb.f.</i>), Kan-Ran(<i>Cymbidium kanran Makino</i>), Nishiki-Ran(<i>Goodyera schlechtendaliana Rchb. f.</i>)
Palms	Kan-non-tiku(<i>Rhapis excelsa (Thunb.)A.Henry</i>)
Ferns	Iwahiba(<i>Selaginella tamariscina (Beauvois)Spring</i>), Matsuba-Ran(<i>Psilotum nudum (L.) Beauv.</i>), Nokisinobu with variegated leaves (<i>Lepisorusthunbergianus (Kaulf.) Ching</i>)
Aquatic plants	Hana-Basu(<i>Nelumbo Adans</i>)
Others	Variegated plants

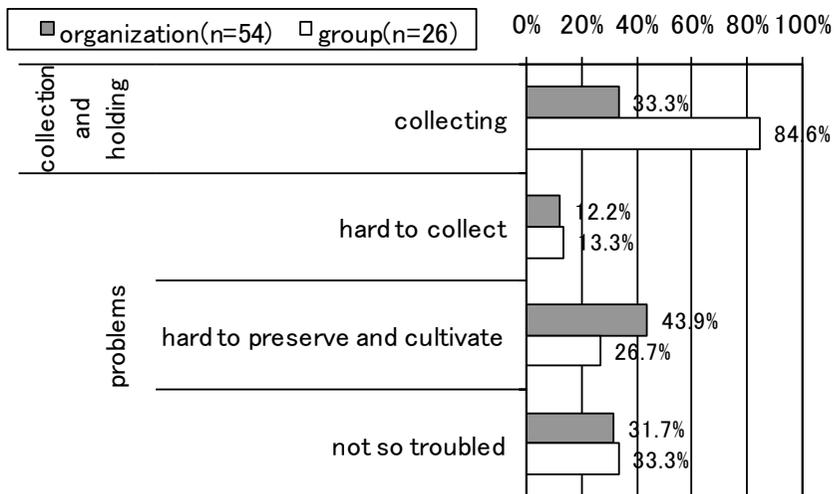


Fig. 1 Problems regarding collections and holdings

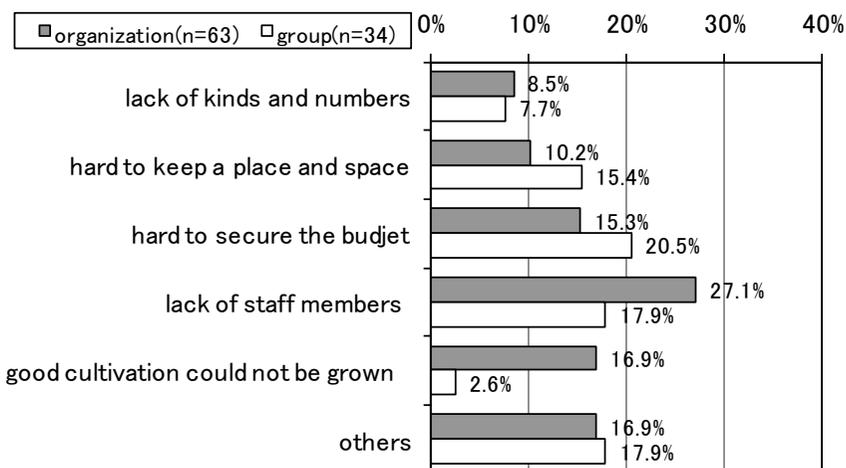


Fig. 2 Problems regarding exhibition

4. Results and Discussion

4.1 Holdings and collections

At present, shown in **Fig.1**, there is a marked difference between organizations such as botanical gardens ('organizations') and preservation groups or individuals ('groups'). 84.6 % of the groups surveyed are collecting traditional

horticultural plants, compared to only 33.3% of the organizations. Nearly half of the organizations who replied to the questionnaire (43%) also reported that 'it is very hard to preserve and cultivate these kinds of plant'. From this, it was gathered that they have somehow been managing to maintain those kinds of plant already established in their existing collections, but were encountering problems with the preservation of additional ones. In the groups surveyed, less than 30% reported that 'it is very hard to preserve and cultivate these kinds of plant', although it was found that they had encountered obstacles to successful preservation and it was suggested that cultivation techniques had not always been successful because of the increasing age of the group members. On the other hand, only approximately 30% of the replies from both organizations and groups stated that they had encountered 'no particular problems'. So it would be unreasonable to conclude that all preservation and cultivation was proving successful, and it may therefore be necessary to examine this further in relation to the specific cultivars involved, their identification and registration, and the actual cultivation techniques used.

4.2 Exhibitions

Fig.2 indicates that most organizations and groups exhibited the traditional horticultural plants they held in their collections. When asked about the problems involved with exhibitions, most organizations cited 'lack of staff members' as the main problem (27 % of replies), followed by 'difficulty cultivating a good specimen for exhibition purposes' and 'it was difficult to keep within the budget', respectively. On the other hand, for the groups surveyed, the most frequent problem cited (20% of all replies) was that 'it was difficult to keep within the budget', followed by the 'lack of staff members', and 'difficulty obtaining a place or space', respectively. Therefore, it was concluded that the main problems for organizations were securing adequate numbers of staff members to take charge of the exhibition, and cultivating excellent plant specimens suitable for exhibition purposes. On the other hand, it was evident that besides financial payments to increase the budget, securing adequate staff members and a suitable space to exhibit plants would also be a great help to most groups.

4.3 Definition of cultivars

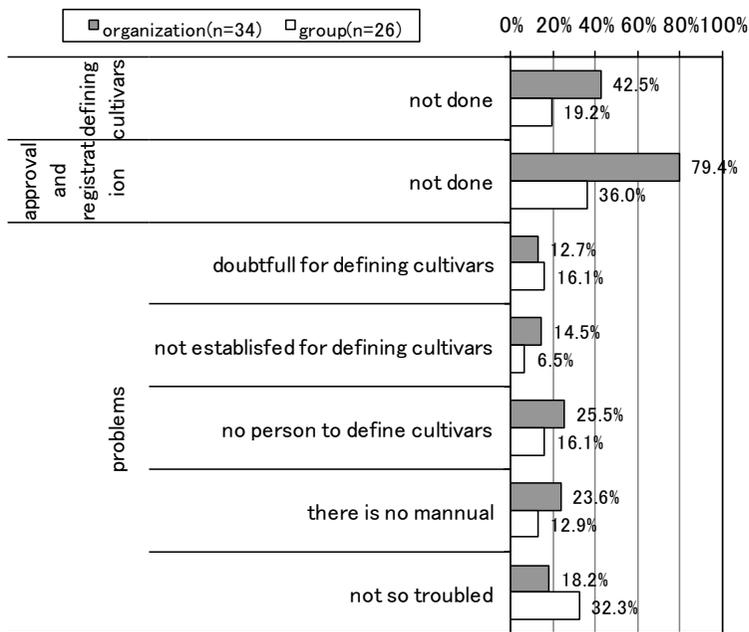


Fig.3 Classifying cultivars and associated problems

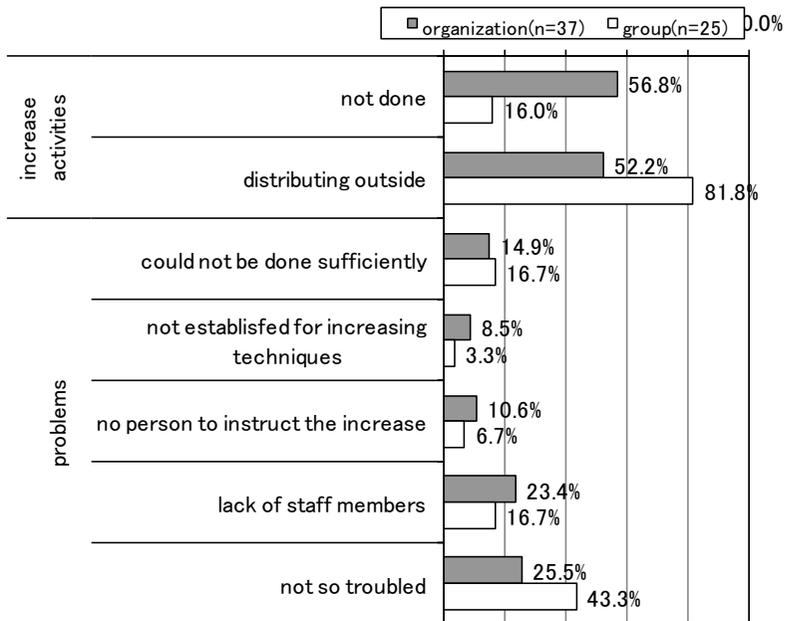


Fig. 4 Plant propagation and associated problems

When asked about the definition of cultivars, shown in **Fig.3**, more than 42.5% of the replies from organizations stated that ‘cultivars definition has not been defined’ whereas the corresponding figure for the groups surveyed was only about 20%. Most organizations (79.4%) also replied that ‘approval and registration are not done’ compared to only 36.0% of groups. A marked difference was therefore noted between groups and organizations. It was concluded that most organizations have not been implementing the cultivar approval and registration process. The number of replies stating that ‘there are no staff members who could define cultivars’ and ‘there is no manual which could be used for defining cultivars’ tended to be higher in organizations than in groups. Conversely, the number of replies stating that ‘there are no particular problems’ was higher in groups than in organizations. Therefore, in both organizations and groups, the level of resources and ability available for the critical evaluation of cultivars was low, and this meant that their ability to define cultivars essential for the preservation and ongoing survival of traditional horticultural plants was also low. In order to preserve and pass on the traditional horticultural plants, it is very important to define and register cultivars objectively and impartially. This would require professional knowledge and experience, therefore it is necessary to construct a public and independent association to deal with the process of defining and registering all cultivars.

An objective system for defining cultivars and facilitating registration and approval, based on specific plant characteristics, should therefore be implemented without delay by some thirdparty organization.

4.4 Propagation

Fig.4 illustrates that plant propagation was ‘not being carried out’ by 56.8 % of the organizations and 16.0 % of the groups surveyed, so a remarkable difference was shown between both. In terms of the rate of ‘distributing the propagated plants, the organizations occupied 52.2 %, while the groups occupied 81.8%. Therefore it was suggested that proceeds of distribution would be assigned to preserving activities in the groups. The response that ‘no particular problems’ were encountered was given by only 25% of the organizations but by 43% of the groups, making this the most frequent response, overall. While the number of responses stating that ‘there aren’t enough staff members’ was high, a much lower number of replies stated that ‘there aren’t enough instructors’, suggesting that staff numbers, overall, were more limiting than the lack of actual leaders or trained instructors etc.

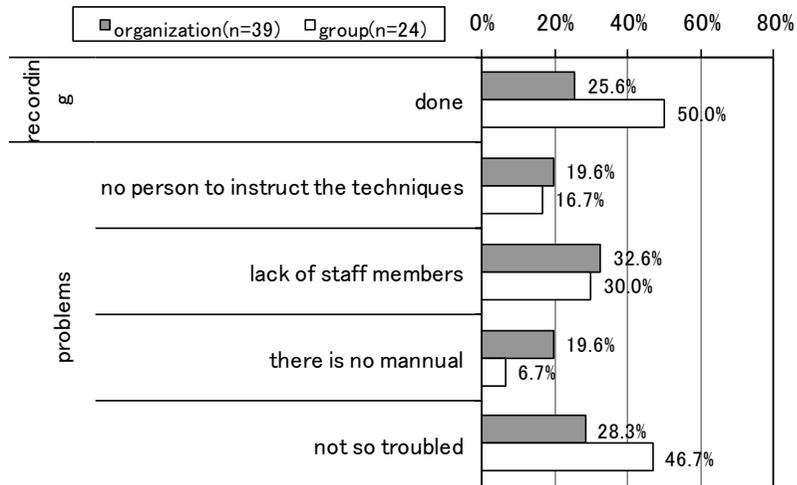


Fig. 5 Problems regarding cultivation techniques

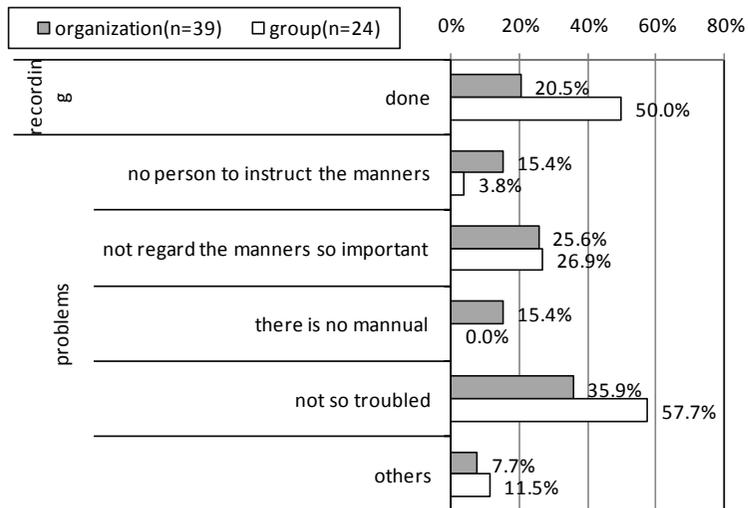


Fig. 6 Plant appreciation and associated problems

4.5 Cultivation Techniques

In response to the question about cultivation techniques, shown in Fig.5, the answers showed that 25.6 % of the organizations and 50.0 % of the groups were involved in the investigation and recording of cultivation techniques. When asked about problems with cultivation techniques, 19.6 % of the organizations cited the lack of a manual' compared to only 6.7 % of the groups, highlighting a marked

Table 4 Traditional horticultural plants in urgent need of preservation and Succession

Japanese name	Scientific name	Organization	Group
Hanazakuro	<i>Punica glanatum cv.</i> Pleniflora	2	0
Manryo	<i>Ardisia crenata</i> Sims	1	0
Kakitsubata	<i>Iris laevigata</i> Fisch	0	1
Sekisyo	<i>Acorus gramineus</i> Soland	2	0
Ha-ran	<i>Aspidistra elatior</i> Blume	1	0
Fukujuuso	<i>Adonis amurensis</i> Regel et Rabbe	1	0
Nishuki-Ran	<i>Goodyera schlechtendaliana</i> Rchb. F.	0	0
Nokisinobu with variegated leaves	<i>Lepisorus thunbergianus</i> (Kaulf.) Ching	0	1

difference between the two. As with the issue of plant propagation, the lack of staff members seemed to be more of a problem than the lack of actual leaders or instructors.

The answer that ‘there aren’t enough members in charge of cultivation techniques’ was received from about 30% of both the organizations and groups. It was thought to be an important challenge to train staff members who possess the necessary plant cultivation skills, which are needed to ensure the preservation and successful propagation of traditional horticultural plants.

4.6 Manner of Appreciation

In response to the question about the manner of plant appreciation, as shown in Fig.6, 20.5 % of the organizations and 50.0 % of the groups replied that ‘recording has not been done’ At least in the groups surveyed, therefore, the need to encourage the public appreciation of importance of the manner of plant appreciation for traditional horticultural plants seems to be recognized much more than the organizations.

Among the organizations, it was therefore concluded that the degree of understanding of the manner of appreciation was low, and that there was little concern over the exhibition of the plants. About 25% of both groups and

organizations felt that 'appreciation manner is not regarded as very important' and 57.7 % of the groups and 35.9 % of the organizations answered that 'it is not a particular problem'. On the other hand, the groups, the degree of understanding of the manner of appreciation was higher than in the organizations, whereas expectations for trainers and the provision of manuals were low. The finding that the 'manner of appreciation' wasn't seen to be important by either groups or organizations suggest, however, that Japanese traditional horticultural plants are perhaps not receiving the recognition they deserve, and we should have to research in further details in the future.

4.7 The cultivars in most urgent need of preservation and ongoing survival

The result of our research in Table 4 indicates that there were 8 species which neither the organizations nor the groups surveyed had in their possession, or either the organizations or the groups surveyed had. In these plants, it could be thought that Nishiki-Ran was protected by some lovers, because of the lack of the system of the organization or the group. There were 7 species of plant (such as Hanazakuro) which either the organizations or the groups surveyed had in their possession.

It could be pointed out that these plants are in urgent need of preservation, because the species could disappear. However, adequate measures for preservation and ongoing survival could not been taken in the organizations, and it seems that some cultivars had been selected, planted and maintained simply for reasons of beauty, rather than deliberately selected from a point of view of rarity or historical or cultural significance, and the need for preservation to ensure ongoing survival. It was concluded that urgent measures for preservation and ongoing survival should be taken in the organizations, because the correct cultivation methods could not always be established, due to lack of technical staff members in charge of cultivation, and because of inadequate cultivar definition, approval and registration processes.

Conclusions

There was a remarkable difference between the organizations and groups which had been involved in plant preservation, with regard to collecting plants, it

was clarified that it mainly depended on the groups in the present situation. Concerning about preserving and succeeding the plants which had been developed as the Japanese horticultural culture, our research brought out clearly in relief that any public organization didn't take concrete measures to preserve and succeed them, while the organizations, such as botanical gardens, didn't take their main role. To ensure the preservation and ongoing survival of traditional horticultural plants, it is necessary to have access to successful cultivation techniques and to properly define cultivars and register them. The succession of these techniques, from one generation to the next, depends on the actual groups involved with each individual species.

In order to preserve and ensure the ongoing survival of traditional horticultural plants in Japan, including those in most urgent need of protection, it is very important to define and register cultivars objectively and impartially, and it is necessary to construct a public and independent association to deal with the process of defining and registering all cultivars.

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VII. Botany and Society

Aromatherapy

Takeo Kawaguchi

1. Introduction

There is some discussion as to the exact meaning of the word aromatherapy and therefore on how essential oils should be used. The word aroma comes from the Latin *aroma*, meaning sweet odor or spice, which is in turn from the Greek *aroma* meaning spice. The word therapy is derived from the Latin *therapia* (Greek *therapeia*), meaning curing or healing. Purists maintain that the definition of the word denotes that the oils are only intended to be used in ways that conform to the meaning of therapy through aroma, which is not by massage or other ways of application but only by inhalation. Of course, this is quite correct if the true sense of the word is rigidly adhered to. Some support is given by Schulz et al (1998), who write that aromatic herbs are effective only when the molecules of their volatile oils come into contact with the nasal mucous membrane through inhalation. The classic prototype of this is smelling salts – a preparation no longer manufactured commercially, but a home-made version is prepared by putting 1-4 drops of essential oil on a tissue and inhaling from it. A tradition of using essential oils in many different ways has, however, built up over the course of time to such an extent that is now almost universally accepted that the word aromatherapy encompasses all methods of applying essential oils. It is important to note however, that this always includes inhalation.

There is also some difference of opinion about the use of the word essential – the traditional term “essential oil” still persists even though the essence of the plant is a poorly defined concept of medieval pharmacy (Guenther 1948) therefore Hay & Waterman (1993) prefer the term “volatile oil” because it refers to the fact that most components of the oils have low boiling points and can be removed from the plant by steam distillation. Nevertheless, people involved in aromatherapy



Essential oils

continue to use the expression “essential oil” and understand the meaning, even though it is acknowledged that “plant volatile oil” is more accurate term.

The subject of aromatherapy involves pharmacy and farming, botany and the human body, medicine and chemistry, toxicology and safety, all so intertwined and interconnected that it is scarcely possible to disentangle the ramifications for the purpose of setting them down without some repetition and much cross-referral.

2. Historical use of essential oils

Plants and their extracts have been used since time immemorial to relieve pain, aid healing, kill bacteria and thus revitalize and maintain good health. Most textbooks on aromatherapy include its history in more or less detail. The word itself was not coined until the 20th century, though essential oils have been employed for countless years in religious rites, perfumery and hygiene. Cedarwood oil, known to have been used by the Egyptians for embalming and hygienic purposes five thousands years ago, was probably the first “distilled” oil. Both the plant and the essential oil of lavender were used by the Abbess Hildegard of

Bingen as early as the 12th century, and by the 15th century it is thought that the essential oils of turpentine, cinnamon, frankincense, juniper, rose, and sage were also known and used in perfumes and medicine by the beginning of the 17th century.



Frankincense



Lavender

3. Modern evidence for the antiseptic powers of essential oils

Towards the end of the 19th century, the action of turpentine oil against the anthrax bacillus was observed, soon to be followed by the research of Chamberland



Cinnamon bark

(1887) that proved the antiseptic properties of essential oils, and then, in the early 20th century, by Cavel's research into the individual effects of thirty-five essential oils on microbial cultures in sewage. Thyme (0.7 ml) was the oil found to be most effective in rendering inactive 1000 ml of culture. Two other well-known oils showing high efficacy were sweet orange and peppermint. The antiseptic power of several oils has now been proved to be many times greater than that of phenol. Certain essential oils have also been shown to be effective against different bacteria, such as lemon, which has some of the best antiseptic and bactericidal properties, neutralizing both the typhus bacillus and *Staphylococcus aureus* in a matter of minutes. Cinnamon kills the typhus bacillus when diluted 1 part in 300.

The bacteriological approach of aromatherapy is an extremely complex field of the utmost interest, opening the way to an ecological understanding and management of the different colonies and floras that live in cohabitations – or at war – within us. Allopathic medicine has begun to realize that the misuse of antibiotics leads to numerous side-effects and sometimes results in chronic disastrous conditions that could have been avoided if medical aromatherapy had been implemented in due time. Today, the properties of herb volatile oils are researched in many centers throughout the world, assessing antibacterial and antifungal properties of essential oils and their constituents.



Steam distiller

4. Essential oil use in industry and aromatherapy

Tens of thousands of tones of essential oils are used by the food industry and a large but declining amount by the perfume industry due to the increased use of synthetic copies. Because they are antioxidants, essential oils are used to protect food from spoilage and the quantities used for toothpastes and mouthwashes have grown spectacularly. The total amount of essential oils used by the aromatherapy profession, though increasing, is nevertheless extremely small by comparison, which contributes to the difficulties of obtaining high quality, pure, natural oils. Some beneficial oils used not to be supplied by distillers, because they were not required by giant users more concerned with quantity and cost rather than quality. Fortunately, in latter years, the number of independent distillers producing essential oils solely for aromatherapy use has increased, though such products naturally tend to be more expensive.

5. Definition of essential oil for aromatherapeutic purposes:



St John's wort



Jasmine in author's garden

- There are only two plant extracts that should be given this name for aromatherapy purposes:
- **Essential oils:** these are plant extracts that have been achieved by steam distillation of plant material from a single botanical source; nothing is involved in this process save water, heat, and the plant material. The essential oil is separated from the condensed steam and nothing is added and nothing is taken away.
- **Expressed oils:** these are the product of citrus fruits, and they are achieved by simple pressing of the citrus peel, without heat or the aid of solvents.
- **Absolutes:** these are aromatic liquids – not essential oils – that are extracted from plant material using solvents, such as hexane and butane, then subjected to alcohol extraction. It is a complex process, yielding a liquid substance called absolute that is totally soluble in alcohol and important in the perfume industry, though still containing traces of solvent.
- **Macerated oils:** these oils are made by putting plant material into a fixed vegetable oil, if those plant molecules soluble in the oil are taken up by the vegetable oil used. Examples of these oils are marigold and St John's wort. These should not be sold in small bottles and passed off as essential oils, but they are important carriers of essential oils and are for use on the skin. Care is needed in the way essential oils are sold to protect both the lay public and aromatherapists. Oil sold for therapeutic use must be whole and unadulterated, accurately identified and labeled, and must have been correctly stored.

Not all plants yield an essential oil and some yield so little that the oil would be too expensive; oils such as hyacinth, lilac, lime blossom, honeysuckle and jasmine do not exist in a distilled form. Their fragrance is extracted by other means and it is incorrect for anyone to name extracts from these plants as essential oils in the context of aromatherapeutic use.

6. Wide-range of applications

Orthodox medicine currently uses plant material to help cure diseases that previously had a high death rate. In early 1970s, four out of every five children with leukemia lost their lives; now, four out of five are returned to health with the aid of vincristine and vinblastine, derivatives of the rosy periwinkle – a plant used

for hundreds of years by tribal healers as a medicine. The snakeroot plant from India is now used to treat hypertension (reserpine). Digitalis, for heart conditions, is produced from foxglove and the well-known rhododendron is used in the treatment of fatigue.

Phytotherapy is the name given to the use of the whole, or part, of the plant for medical purposes. Aromatherapy and aromatic medicine are branches of this category, but use only distilled essential oils, expressed citrus oils and hydrolats. Plant oils are simple to use and administer, yet can compete with the steroids and antibiotics used in allopathic medicine today without the body's defense mechanism becoming exhausted or developing tolerance to them. The basic reason that accounts for the diversity of conception and application of aromatherapy lies in the very nature of the aromatic substance. Essential oils have many properties that make them highly suitable therapeutic substances.

- The capacity to effect cutaneous penetration quickly and easily.

Being endowed with the capacity to influence the mind through their powerful impact on the human olfactory system. They were traditionally used in analeptics (a restorative remedy for states of weakness frequently accompanied by faintness and dizziness) to stimulate the olfactory nerve and the sensory trigeminal nerve endings causing a reflex stimulation of respiration and circulation.

Thus it was perhaps inevitable for aromatic substances to find healing application in so many areas.



Rhododendron in the herbarium of JIU

7. Powerful healing agents

Many plant extracts used in the production of conventional medicines are, like the foxglove, poisonous and therefore exceptionally low doses are employed. Some essential oils are also toxic when used incorrectly and the most powerful of these are not normally available to aromatherapists. Essential oils are concentrated and intensely energetic in their effect, so very little is needed for successful treatment – dilutions generally being in the range 0.05-3%, occasionally up to 10%, depending on the oil(s) used, but their use undiluted may be suitable under certain circumstances. Apart from the difference in the intensity of the aroma, no apparent benefit is gained from higher concentrations, particularly where the problem is an emotional one, though more concentrated solutions are used in certain medical conditions in aromatic medicine.

It cannot yet be proved exactly how essential oils work, but research and extensive anecdotal evidence exist to prove that they do work. In the distant past, essences were used to heal wounds, inhibit the decay of flesh and reduce the spread of infection – all without anyone knowing how they worked, just as the humble aspirin was in use for many years before anyone knew its mode of action.



Foxglove in the herbarium of JIU

8. User-friendly

“Bios” is the Greek word for life and essential oils may be classed as probiotic, as opposed to antibiotic. To illustrate this point, antibiotics kill not only harmful bacteria, but also the beneficial flora needed to keep us healthy, leaving the body in a weakened state. Carefully selected essential oils kill only the bacteria inimical to the successful functioning of the body.

Many essential oils possess antiviral and fungicidal activities, and natural, whole essential oils can be used on living tissue with minimal unwanted effects – unlike some synthetic drugs however successful against their intended targets. Also, the human body accustoms itself to the effects of chemical synthetics, leading to escalating doses. This has not been found to be the case with essential oils, which retain their effectiveness in repeated applications and can in fact strengthen

the living tissue while killing off the unwanted bacteria. This may be due to the fact that essential oils are natural products and that their composition is not fixed but tends to vary from season to season.

Compared to the very high price of medicines (because of tremendous research and development costs) essential oils are extremely inexpensive – a factor that should interest those in charge of public health funds. Not only that, they are pleasant to use for both patient and therapist. In many hospitals and hospices they are used not only to improve the quality of life but also in waiting rooms to relieve the anxiety of relatives and friends. More specifically, they can be used in place of secondary drugs, which might be prescribed to counteract the iatrogenic effects of primary drugs.

9. Areas of use

Essential oils have been found to aid relaxation effectively, both pre- and postoperatively, to regenerate tissue in cases of severe burns and inflammation, and to relieve pain in cases of rheumatoid arthritis. They have helped to improve the quality of life for the terminally ill and have also found important uses in



Antibiotics

maternity care. They are used more and more to help people with learning disabilities and in elderly care, particularly with regard to dementia, as well as being used extensively to improve or uplift a patient's state of mind. The effect of attitude of mind on a person's health is being recognized.

By far the majority of essential oil users are outside the medical profession, some people using them merely on instruction from one of the many books written for the general public on the subject. They are simple to use and it should come as a relief to general practitioners that minor everyday ailments such as a sore throat or a winter cold, and also some chronic disorders like bronchitis, sinusitis, and rheumatism can be treated in the home easily and successfully.

All this is achieved by anyone, without professional medical skills. However, in France, medical doctors prescribe essential oils for internal use in capsules, diluted in alcohol or in suppositories and pessaries as well as using them externally in dressings, inhalations, ointments and in foot, hand or whole body baths although massage is not used. The original concept of aromatherapy was to use the essential oils in massage only – suitably diluted in a fixed vegetable oil. Aromatherapy now includes inhalation, baths, compresses and in some places, the use of pessaries and suppositories.

In this decade, essential oil therapy has been introduced into many hospitals, hospices, and clinics, but more progress must be made, that is, it needs the medical profession not only to take a greater interest in essential oils and demand research studies but also to use its professional skills to use these precious commodities to their fullest capabilities in order to bring the benefits of this aromatic therapy to all hospitals throughout the world in the 21st century.

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How Essential Oils Enter the Body

Takeo Kawaguchi

Introduction

Essential oils follow three main pathways to gain entry to the body: ingestion, olfaction and absorption through the skin. Ingestion is little used in Japan. Of the two remaining pathways, inhalation is a very effective method and indeed is regarded as the only method truly deserving the name aromatherapy. However, topical application via the skin has also been found to be effective, and the route selected depends on the problem being helped.

Olfaction

Access via the nasal passages is indisputably the quickest and most effective route in the treatment of emotional problems such as stress and depression. This is because the nose has direct contact with the brain, which is responsible for triggering the effects of essential oils regardless of the route they use to gain access to it. The nose itself is not the organ of smell, but simply modifies the temperature and humidity of the air inhaled and collects any foreign matter which may be breathed in. The olfactory nerve is responsible for the sense of smell and serves the receptor cells, of which there are two groups of about 25 millions each occupying a small area (of about 4 cm²) at the top of the nostrils.

When essential oils are inhaled, the volatile molecules in the oils are carried by eddy currents to the roof of the nose, where delicate cilia protrude from the receptor cells into the nose itself. When the molecules lock onto these hairs, an electrochemical message is transmitted via the olfactory bulb and olfactory tract to the limbic system. This may trigger memory and emotional responses via the hypothalamus acting as relay and regulator, and cause messages to be sent to other parts of the brain and the rest of the body. The received messages are converted into action, resulting in the release of euphoric, relaxing, sedative or stimulating neurochemicals as appropriate. The limbic system, which developed 70-million years ago and used to be called the rhinencephalon (from the Greek, rhis = nose, enkephalon = brain). The limbic system is heavily implicated in the

expression of emotion, although whether it generates emotion or merely integrates it is not clear. The body can replace olfactory nerve cells, underlining their importance.

The sedative aromas such as *Origanum majorana*, *Lavandula angustifolia*, *Chamaemelum nobile*, *Chamomiila recutita* and *Citrus aurantium* cause stimulation of the parasympathetic nerve, which then releases the neurochemical serotonin, whereas stimulating aromas such as *Rosmarinus officinalis*, *Citrus limon*, *Ocimum basilicum* and *Menta x piperita* will affect the sympathetic nerve which then releases noradrenaline.

Inhalation and the mucous membranes

When inhaling any vapor, some molecules from it inevitably travel down the pathway to the lungs where, if they are appropriate essential oils, they can have an immediate and beneficial impact on many breathing difficulties. In the nose the endothelium is thin and the site is close to the brain, therefore it must be assumed that essential oil molecules reach the local circulation and the brain fairly easily and quickly. On their journey to the lungs some molecules are undoubtedly absorbed by the mucous linings of the respiratory pathways and the bronchi and multitudinous bronchioles, where access is very easy. Arriving at the point of gaseous exchange in the alveoli, the tiny molecules are transferred to the blood circulating the lungs. It can be seen that deep breathing will increase the quantity of essences taken into the body by this route. Fortunately, ill effects from inhalation of essential oils normally used in aromatherapy are rare.

Methods of inhalation

Inhalation is an unobtrusive way of using essential oils in a healthcare setting. They may be given via a tissue, the hands, or a vaporizer, for example, and all are effective in the appropriate situation.

Tissues

Inhalation from a tissue with 5-6 drops of essential oil is most effective for immediate results, requiring two or three deep breaths to ensure good contact with the cilia. To give further benefit, and to be easier for use with children and the elderly, the tissue can be placed inside the shirt, blouse or nightwear so the effects

may continue as the heat of the body causes the essential oil molecules to evaporate and float upwards to the nose. Firm tissues such as kitchen towels hold the aroma longer than paper handkerchiefs.

Hands

This is an excellent method, but should be confined to emergencies only and is not suitable for children. A solitary drop of essential oil should be put into the palm of one hand, which is then rubbed briefly against the other to disperse and warm the essential oil. The cupped hands should then be placed over the nose, avoiding the eye area.

Vaporizers and diffusers

Possibly the most favored way of using inhalation in a healthcare setting at the moment is from a vaporizer. This liberates the lightest molecules from the essential oil first, releasing the heavier ones progressively. Although there are many different types of vaporizers available, only electric ones are considered completely safe. Electric vaporizers should be thermostatically controlled at a low temperature, preventing the essential oils from becoming too hot. If this occurs, not only are they used up too quickly to be economical but also the residual heaviest molecules may burn off, producing an unpleasant acrid smell.

Diffusers are more efficient in that they push out all the differently sized molecules at the same time. Unlike vaporizers using heat, there is no burning of residue when the essential oil is used up. Their only disadvantage is their price, which can be up to three times greater than that of an electric vaporizer. One diffuser currently on the market has a time switch, ideal for hospital use.

Absorption via the skin:

Until the second half of the last century the skin was thought to be almost impermeable. This old idea still persists, even though the skin is known to be a poor barrier to lipophilic substances such as essential oils. It is slightly permeable to both hydrophilic substances and water itself, even though the skin has developed as a barrier specifically to resist water. This protection is vital because water comprises 90% of any cell.

There has been a considerable amount of research regarding pesticides and the skin. Pesticides, which dissolve in essential oils, are lipid-like and can therefore get through the skin. The skin's success as a barrier is due in the main to the stratum corneum, the tough and durable, self-repairing keratinized layer, which is only about 10 µm thick. Once a chemical gets past the epidermis, the rest of the journey into the body is easy, because the presence of lipids in all cell membranes negates the dermis's effectiveness as a barrier. There are many factors which dictate the rate and quantity at which any given substance penetrates the skin, but it is now generally recognized that the skin is a semi-permeable membrane susceptible of penetration by substances to a greater or lesser degree. Obviously the physicochemical properties of the molecules such as the molecular weight and spatial arrangement, liposolubility, coefficients of diffusion and dissociation are fundamental to skin penetration.

On account of their solubility in the lipids found in the stratum corneum, lipophilic substances such as essential oils are considered to be easily absorbed. The absorption of organic compounds with anionic or cationic groups takes place when they are found in undissociated form: it depends however on their dissociation constant and on the pH of the substance and the skin. Most essential oils used in aromatherapy pass through the skin and the organism and can be detected in exhaled air within 20-60 minutes.

Once the essential oil constituents have passed the epidermis and enter the complex of lymph and blood vessels, nerves, sweat and oil glands, follicles, collagen, fibroblasts, mast cells, and so on, they are then carried away in the circulation to pervade every cell in the body.

Methods of percutaneous absorption

Many of the techniques used on the skin entail the use of water, vegetable oil or a bland lotion to dilute and spread the essential oils over an area of skin.

Compresses:

Compresses are sometimes required on open wounds such as leg ulcers, bedsores and boils, and on bruising or areas of severe localized pain such as arthritis, stomach pain and fractures. Nonadherent dressings should be used on open wounds. The size of compress, number of drops of essential oils and amount of

water used is dependent upon the size of the area to be treated. A septic finger requires only a minuscule square of the dressing material chosen, and 30 ml of water to which 2 drops of essential oil have been added, whereas a swollen rheumatic knee would require a piece of cloth large enough to cover the swelling, and a small basinful of water containing 5-6 drops of essential oils. As always, the quantities of essential oil should be halved for children and the elderly.

The chosen material should be immersed in the mixture of water and essential oil, squeezed gently and placed over the required area. It should be covered in the normal manner, and a piece of cling film can be ideal as a first layer to prevent evaporation of the essential oils. The compress should be left on for about 2 hours, or overnight if practicable.

Gargles and mouthwashes:

After the removal of tonsils or complicated dental surgery, gargling with essential oils helps to relieve any pain or inflammation, stem blood flow and aid healing. At the same time the oils are antiseptic to the mucous surfaces. Two to three drops in a quarter of a tumbler of water is all that is needed, with the most important rule to follow being that the water should be stirred before each mouthful to disperse the essential oils each time. For children, blend only 1 drop of essential oil in a teaspoonful of honey before adding the water.

Sprays

Sprays can also be used as a method of application when the client is unable to be touched, for example in the case of severe burns, zoster or wounds. A higher concentration is needed when treating burns this way, for example 15-20 drops in 50 ml of distilled or sterilized water.

Baths

A valuable method of use involving water and inhalation is the addition of 6-8 drops of essential oils to the bath water after running it to the correct temperature. There are those who advise adding the essential oils to another medium first, such as vegetable oil, dried milk, high proof vodka, bath bubble mix, etc. While useful for certain skin conditions, vegetable oil is not necessary in most circumstances, and it can leave an oily ring on the bath. Although the essential oils are not completely soluble in water, it is a simple matter to disperse them by vigorously agitating the

water. For water births the essential oils are best dissolved first in a small amount of powdered milk.

Inhalation plays a valuable part in an aromatherapy bath, and there is a great deal of skin penetration as well. For maximum benefit, the client should remain in the bath for 10 minutes if possible. Blend 3-4 drops in honey or dried milk for children and the elderly.

Foot-, hand-, and sitz-baths:

It is sometimes easier to use a washing-up bowl for bathing individual areas. The sitz-bath, for example, is ideal for hemorrhoids and stitches after childbirth. Three to four drops of essential oils are needed, and a kettle should be available, to keep the bath warm for the full 10 minutes. This method may not be found necessary for children but, should the occasion arise, remember to follow the recommendation above for baths.

VIII. Environmental Ethics

A Critical Approach to the Japanese Collective Idea of “Nature”

Akitsu Taki

1. Introduction

The Japanese words for love and nature, each *ai* 愛 and *shizen* 自然, both colloquial in the 21st century, were brought into use in the late 19th century as translations from the European languages. Despite the historical fact, most of the Japanese people today, working at office or factory isolated from “nature”, if asked whether they love nature, will probably say definitely yes, without thinking over what the *yes* implies. They will often go to hardly approachable places on holidays and enjoy amazing landscapes there. They are well aware, however, that the access to those places has been provided owing to the development of the land *en route*, that is, the highways, bridges and tunnels through which to approach there. One can take many other examples like this. People living in Japan are more or less aware of their direct and indirect commitment to “modifying”, if not “destroying” or “degrading”, “nature” and yet most of them will not deny that they “love” “nature”. That is also the case more or less with workers in the other industrialized countries. Too much civilization, convenience and artificiality in their daily life may arouse a kind of nostalgia. This might well explain the present collective psychology but how has such mentality been socially formed? Truly, it is often said that Japanese people are collectively a nation who ‘love’ ‘nature’. Even so, why could they have fostered such a mixture of personally “loving” but collectively radically modifying “nature”? My answer, apart from its generalizability to people in the other industrialized countries, is that Japanese people, living in a proper tradition in which the sensible insentient things such as mountains, rivers and trees are idealized or deified, have been collectively committed *both* to assimilating their individual *egos* to their family or country as an idealized totality *and* to exploiting the concrete sensible world for the protection of such totality. This collective commitment, to whatever extent under the pressure of social conformity

in each historical age, has involved an ethical egoism: utilizing other lives as a means for one's own existence. One who is living in a local community in the Japanese archipelago, therefore, should deliberately in quest for extra-communal distributive equity disengage oneself from this collective commitment of the Japanese previous generations'. I will argue for these contentions.

2. Methodological Preliminary Remarks

A social group's collective, or a single person's, mostly a literary author's or work's, idea of nature is comparatively a favorite topic in the Japanese modern literature. National Diet Library Online Public Access Catalog lists among the items printed from the late 19th century on nearly 1400 books or articles including in their title or subtitle "Idea of Nature" *shizen-kan* 自然観 or "Concept of Nature" *shizen-gainen* 自然概念, as is the same with "Idea of Life and Death" *shi-sei-kan* 死生観 and "Idea of Human" *ningen-kan* 人間観, and especially nearly 130 books or articles entitled "A/The Idea of Nature the Japanese People Hold" *Nihon-jin no shizen-kan* 日本人の自然観.

However, the approach to the subject matter concerned, that is, how a or the collective idea of "nature" attributed to the Japanese people can be justifiably deduced, is problematic. (1) People have lived and formed a society in the geographical area in and around the islands the 21st century nation state Japan governed under its administration but the time when the ruling class used the title "Japan" 日本 to call to the Chinese dynasty the area they governed is not earlier than the late seventh century CE. The hypothesis that all the people living in the Japanese archipelago were conscious of living in Japan all the time in history is clearly wrong. (2) Some people living in the Japanese archipelago have expressed in literary prose or verse their attachment to, or praise of, the sensible things around them, such as mountains, rivers, climate, air, flowers, trees and familiar animals. However, how could one justifiably deduce from those limited resources a collective idea attributed to all the "Japanese" people? (3) It is a logical fallacy to deduce from someone's discourse on those sensible things his or her concept of nature. The deduction doubly begs the question³. One who tries thus already presupposes what it is to be nature and what the Japanese people presupposed it

³ For such deduction, see Tsuda (1916) 393.

was to be nature. (4) At least before the word *shizen* 自然 began in the late 19th century to be used as a translation from the word for nature in the European languages, the word for nature in the European languages was not in use among the ordinary people living in the Japanese archipelago. Even after that, it has been polysemous⁴. (5) The discourse concerned with ‘nature’ in the past, even if collected without committing logical fallacies, would be limited, not universal. Some literary people among the ruling class in the past might have spent their leisure time composing discourse on what seems to modern literary people related to ‘nature’ but there used to be non-literary and even illiterate many. A literary few’s praise of ‘nature’ is perhaps a kind of detachment, but not disengagement, from the community’s collective commitment. (6) Some Buddhists or Shintoists also literarily worked on what modern literary people call ‘nature’. Under the influence of a Chinese Buddhism, the Tendai School⁵, they advocated that even the insentient such as mountains, rivers, trees, grasses, rocks etc., had the same potency of deciding to, and doing successfully, go beyond the sensible world (or become a Buddha in Buddhism) as human beings had⁶. They practiced such

⁴ Yanabu (1977); Soper (1995).

⁵ In Buddhism, Buddha-nature, *Buddha-dhātu* 仏性, also called buddha-embryo (*tathagatagarbha* 如来藏) or thusness (*tathata* 真如), is what inheres in a thing and makes it what it is to be a Buddha. Buddha-nature liberates the things in which it inheres from the world where they are annoyed with being in or out of agony and delivers them into *nirvana* Buddha enters, where the state of being in or out of agony expires. What kind of thing finds in itself Buddha-nature, starts to train itself to be what it is to be a Buddha, and perfects itself in realizing the Buddha-nature varies among schools. In China, whereas Fazang, known as Hozo in Japan, 法藏 (643-712), from the Huayan school 華嚴宗, denied trees and plants Buddhahood for the reason that the insentient were not open to awakening (Akao (1984) 407), Jizang, known as Kichizo in Japan, 吉藏 (549-623), extending Buddhahood to the insentient for the reason that things in the phenomenal world are not out of the Middle Way, Buddhahood (一色一香皆為顯道(T45.94c)('T' is an abbreviation for *Taisho Tripitaka*)) (Okuno (1998) 93-96.), that under the aspect seen by the perfect wisdom (理内) the insentient are of Buddhahood (草木亦有仏性 此是对理外無仏性 以弃理内有仏性) ('On Buddha-nature' *The Principle of Mahayana Buddhism* 『仏性義』 『大乘玄論』) (T45.40b) (Shirato (1998) 19) and that direct and indirect causation are not different (以依正不二故、衆生有仏性則草木有仏性 (ibid., T45.40b-c)), yet finally deny trees and plants the Buddhahood open to awakening (Miyamoto (1961) 683-6). However, earlier in the Tendai order, Zhiyi 智顛 (538-597) in his lecture entitled *Great Meditation* in 594 (摩訶止観) already proposed that things in the phenomenal world are not out of the Middle Way 一色一香無非中道 (T46.1c) (『円頓者、初縁実相造境即中無不真实、繫縁法界一念法界 一色一香無非中道』 'The perfect and instant attainment of Buddhahood means recognizing that the actuality is in the chain of causation from the beginning of practice; and that the object is the middle, not out of the truth. All the beings and phenomena are interdependent and an ideation at an instant include the whole of the universe. Neither a twig of flower nor a twist of incense is out of the Middle Way.' (tr. by A. Taki)). Based on this proposition of Zhiyi's, Zhanran, known as Tanzen in Japan, 湛然 (711-782), extended Buddha-nature to the insentient in his exegesis of Zhiyi's lecture (『摩訶止観輔行傳弘決』). He disputed with those who denied Buddha-nature to the insentient in his book entitled *Disputation by Dint of the Sharp Scalpel* 『金剛鐮論』, saying that Buddha-nature inheres in "one grass, one tree, one pebble, and one dust", for the reason that the awareness of the truth inherence and the practice contributing to the awareness as well as the truth intrinsic to the sentient also inhere in those insentient ("That is to say, one Buddha-nature and one chain of causation inheres in one grass, one tree, one pebble and one dust each and they are equipped with causation by intellect and practice" (tr. by A. Taki) 乃謂一草一木一礫一塵。各一佛性各一因果具足縁了(T1932, 784b)). For some intellectual receptacle through which some Japanese Buddhists were to extend Buddha-nature beyond animals into plants, see Miyamoto (1961) 673; Imamichi (1983) 4-6.

⁶ Saicho, 最澄 (767-822), founder of the Japanese Tendai school, already mentioned the insentient's Buddha-nature in his exegesis

going-beyond on “mountains”, meaning at their temples and shrines on a hill or a mountain. Japanese lay people might have partaken of such an idealized conceptual scheme but in practice did not renounce their worldly existence. Hence, like a literary few’s, a religious few’s self-unification to ‘nature’ is collusive with the community’s collective commitment.

For these reasons I will make a detour around these faults often found in the previous work and focus on both the rulers’ policies over people’s life conditions and people’s commitment to the policies. To be specific, instead of discussing the so-called Japanese collective idea of ‘nature’, I will enquire through the rulers’ policies how people in the Japanese archipelago have dealt with their own life conditions. This approach requires much historical evidence in the detail but in order to show a methodological contrast with the previous approaches I will in the main body below prefer to concentrate on my central argument while leaving some specific supports for further enquiry.

on Zhanran’s *Disputation by Dint of the Sharp Scalpel* (『註金剛鐮論』)(『伝教大師全集』3, 314 (Fuchida (2003) 60)) and in his book entitled *Questions of the Tendai Order* 『天台宗未決』 (‘Under the aspect of an instant ideation shedding over the three thousand realms there is no difference between the sentient and the insentient. . . the essence of the entities is identical with, not different from, Buddha-nature’ 三千一念中 心悉皆具足 情与非情 本来不二、 . . . 法性即仏性不異也) (Shirato (1998) 23). An’nen 安然 (841?-915?) was the first to propose a theory of the attainment of Buddhahood by trees and plants and admitted in his *An Exegesis of the Attainment of Buddhahood* 『樹定草木成佛私記』 and *An Exegesis of the Rise for Awakening* 『菩提心義抄』 that trees and plants, although insentient, spontaneously decide and train themselves for the attainment of Buddhahood, thus perfecting themselves into Buddhahood. Ryogen 良源 (912-985), according to a later edition of biographies of Japanese Buddhists, the *Genko-Shakusho* 『元亨釈書』 3.4 and the *Taihei-ki*, vol. 24 『太平記』, in dispute with Chuzan 仲算, from Hosso-shu, on the universalizability of the Buddhahood attainment 一切衆生皆成仏 at the *Owa* Doctrinal Dispute in 963, contended against Chuzan’s denial of practicing Buddha-nature. In the writing transmitted under Ryogen’s authorship, entitled *Trees’ and Plants’ Determination, Training and Buddhahood Attainment* 『草木発心修行成仏記』, it was categorically stated that trees and plants determine, train and attain Buddhahood. Genshin 源信 (942-1017), a disciple of Ryogen, in his book entitled *An Exegesis on the Three Ways of Buddha-Body* 『三身義私記』, admitted the insentient’s Buddhahood attainment but denied the spontaneity in determination, practice and Buddhahood attainment. His reason was that the sentient was to be distinguished from the insentient and that there was no documentary evidence for the spontaneity (Fuchida (2003) 61). However, Genshin described a flower with which he honoured and worshipped Buddha as mediator to the attainment of Buddhahood in saying, “When I honoured and worshipped Buddha, dedicating a petal of flower and burning a twist of incense, then since ‘the phenomenal world are not out of the Middle Way’ a Buddha is the whole truth, and therefore a Buddha is the whole Buddha; and therefore, innumerable Buddhas in the ten realms of the universe are at the same time honoured and worshipped” (*On the Idea of Thusness (tathata)* 『真如觀』, quoted in Watanabe, Y. (2000) 4-5). Among the later Buddhists of the Tendai school, however, it was open to question whether determination and training were admitted to trees and plants. They raised the questions of why insentient entities could determine or practice and why it is not a sin to kill trees and plants if they are sentient. Among several works of the vocal parts of the *Noh* theatre 能, *yokyoku* 謡曲, in the 14th century, trees’ and plants’ Buddhahood attainment is referred to as the venerable teaching of Buddha but in the *Sumizome-zakura*, *Ink-dyed cherry-blossom*, under the source of *Intermediate-State Sutra*, 中陰經 (Miyamoto (1961): 674.). However, in the sutra entitled *Intermediate-State Sutra*, 中陰經, a story of Buddha’s preaches in the period after *nirvana*, translated by Chu Fo-nien 竺佛念 in the era of Late Qin (384-417), trees’ and plants’ Buddhahood attainment is not mentioned. Therefore Miyamoto concluded that trees’ and plants’ Buddhahood attainment was invented in Japan (Miyamoto (1961) 264; see also Shirato (1998) 17-18).

First of all, during the 70 years' political economy of Japan under the 1946 constitution after the defeat in the Second World War, almost all the Japanese political leaders have professed that the country Japan is small in area and short in resources, food and energy, and advocated from this presupposition that Japanese people can hardly realize their full self-sufficiency in food and energy.

In what follows I will propose two hypotheses of mine, one factual and another evaluative. The first one is that the attitude of belittling one's own country mentioned above, although at least admitting of a historically practicable alternative, has been continuous in the past rulers' policies in the Japanese archipelago, perhaps since the storage economy started during the age of hunting and gathering. The second is that the policy of partly or wholly both inter-communalizing and intra-communalizing some other communities cannot be justified until realizing the equity in distribution among all the other communities is in parallel envisaged within the limits of the global total self-sufficiency.

3. A Theory on the Belittling of One's Own Territory

Saying simply that a country is small involves *secundum quid*. The proposition is not meaningful unless the speaker determines by what measure it is small. Even if it is meant to be "small in area" as usually supposed, it is still not absolutely small. A given area is surely absolute in quantity. For example, the area the present administration of Japan claims to govern is about 380,000 square kilometers. However, whether or not one should value the given area relatively low depends on how one should measure the quantity. Three square meters is sometimes too small and sometimes too large. Furthermore, a country relatively low in some quantity can be relatively high by another measure. A "small" country is not always low by any other measure. Furthermore, an increase in area does not necessarily entail an increase by any other measure. Bigger does not necessarily entail better by any measure. Repeating "Japan is small" is, therefore, not a rational attitude.

4. A Practical Alternative to the Self-Belittling of Japan

A country at one time can be becoming smaller in area for its population increase. It can also be becoming shorter in a resource for the population increase. However, since the rate of self-sufficiency in a resource is a quotient of the total amount of the resource divided by the population, neither enlarging the resident area nor acquiring the resource from the outside will be the only solution. Decreasing the population in absolute quantity is an alternative in theory. No member of a community, however, would agree to choose this alternative. However, decreasing the population increase rate is an alternative collectively more practicable. Furthermore, a higher rate of self-sufficiency will be a good alternative. Likewise, even if the highest possible efficiency in the use of the resource concerned does not meet the full self-sufficiency, developing some alternative resource will be a third alternative. Eventually, the time may come when all the possible alternatives are not going to redeem the full self-sufficiency. However, it does not follow that filling the shortage by enlarging the territory is collectively preferable to depopulation.

A practical alternative used to be collectively chosen in history in the Japanese archipelago. The local and national administrators in the Tokugawa regime, although potentially not without the high spirits of economic growth, constrained themselves from enlarging their territory beyond their boundaries. Reliable statistics show that net agricultural product supported the full self-sufficiency in food⁷. Also people lived without having to import raw materials from overseas. Even after a large-scale international trade started in the late 19th century, as reliable statistics suggest, the net agricultural product did not decrease. After the defeat in the Second World War some political leaders⁸ and agronomists⁹

⁷ See Crawcour (1979); Saito (2013) 246-248; 「石高」 ‘*Kokudaka*’, *Wikipedia*. Townsend Harris, U.S. merchant and first consul general in Japan suggested Japan’s self-sufficiency at that time (Consenza (1959²) 330; 485).

⁸ Prime Minister Tetsu Katayama (1887-1978), graduated from the Imperial University of Tokyo, a lawyer and the first Chairman of the Japan Socialist Party, discussed on 1st July 1947 in his statement of his cabinet’s policy in the first Diet session under the 1946 Constitution after the Second World War Japan’s economic reality at that time and its ultimate cause (Katayama (1947)) but did not mention as a possible cause that Japan had been, or originally was, small and poor in resources and food. Nor did Prime Minister Hitoshi Ashida (1887-1959), DLL (graduated from the Imperial University of Tokyo, diplomat and the First President of the Japan Liberal Party) in his statement of his cabinet’s policy on 20th March 1948, but rather avowed to seek for a collective self-sufficiency in the middle of the hardships immediately after the war (Ashida (1948)). See also the Economy Stabilization Headquarter (1947), *Summary, A Report on the Reality of Economy*.

⁹ A few years after the end of the war, around the time when the pre-war assumption of Japan’s deficiency in land and resources appeared in public again, there were some agronomists who did not state or even suggest that it was theoretically or practically impossible that Japan was self-sufficient in food. For example, see Kimbei Toi, 東井金平, Director of Foreign Affairs, General Institute of Agriculture, Ministry of Agriculture and Forestry 農林省農業総合研究所海外部長, (1951) 8-9 (graduated from the University of Keio, member of the journal *Shakai Shiso* (Social Thoughts), local government officer of Kobe City, in the pre-war time

claimed that the full self-sufficiency in food was not impracticable. With machines and chemicals, the national net rice product in 1980's rose up to 10 million tons, that is, nearly 6.6 million *kokus*, the amount equal to the annual food consumption by nearly 6.6 million people¹⁰. Surely the net rice product has not been far enough to feed the total population living in the Japanese archipelago but the extents of ordinary or abrupt annual shortage have not been so much as to justify the policy of collective expansionism for future food security (see *Appendix*).

5. The Japanese Post-War Political Discourse of Self-Belittling

After the defeat in the total warfare Japanese policy-makers and policy-drafters¹¹ under the democracy of the 1946 constitution have continued mentioning in public that their country is small in area and short in resources¹². So have Japanese business leaders¹³. Forced by the allied forces' occupation

(Umeda (1998) 48). Some others stated that Japan's food deficiency was due to political failure (S. Iwamatsu, later Professor of Economy at the University of Nagasaki and President, the Japan Congress against A- and H-Bombs (1950) esp. 38-39; Yasuo Kondo, pre-war Professor of Agronomy, Imperial University of Tokyo (1951) 66). With reference to England's early 19th-century policy of free trade against its domestic agriculture and/or to the advisor for the Supreme Commander for the Allied Power, William J. Logan's 1949 instruction of resource importation priority against the background of the surplus cereal products in America, they argued that the Japanese small-scale land management adaptable to the cultivation of rice and wheat did not agree with the policy that the national economy will become better in the international division of labour if a nation imports low-priced agricultural products and offers them to the workers in the division of manufacture, thus forcing the agricultural management to be rationalized and shifting an excess of domestic workforce from the division of agriculture to the division of manufacture. Even among some present agronomists Japan's pre-war political failure in the self-sufficiency in food is suggested (see Inoue (1973); Iinuma (1979); Hayashi (1996). For England's early 19th-century policy of free trade against its domestic agriculture, see D. Ricardo (1817) *contra* Malthus (1815). Malthus (1815) argues that the importation of low-priced corn would damage the home agriculture, saying 'I think it must be allowed further, that no loss, in proportion to its amount, affects the interest of the nation so deeply, and vitally, and is so difficult to recover, as the loss of agricultural capital and produce (7).' He also argues that international free trade is impracticable, saying, '...; in short, that it must be allowed that a free trade in corn would, in all ordinary cases, not only secure a cheaper, but a more steady, supply of grain. / In expressing this distinct opinion on the effects of a free trade in corn, I certainly meant to refer to a trade really free—that is, a trade by which a nation would be entitled to its share of the produce of the commercial world, according to its means of purchasing, whether that produce were plentiful or scanty. In this sense I adhere strictly to the opinion I then gave; but, since that period, an event has occurred which has shewn, in the clearest manner, that it is entirely out of our power, even in time of peace, to obtain a free trade in corn, or an approximation towards it, whatever may be our wishes on the subject.' (10-11) The ultimate reason is that intra-communal trade is not everlastingly secured beyond a nation state's sovereignty (17-18).

¹⁰ Yano Tsuneta Memorial Foundation (ed.) (1981) 177-178.

¹¹ For the bureaucrats under the 1946 constitution as policy-drafters, see Shiroyama et al. (1999); Nishio (2003²) esp. 98-108.

¹² The Economy Stabilization Headquarter (ed.) (1947) *Summary* 10; *ibid.*, 'The People's Living'; Aoki (1949); The Ministry of International Trade and Industry (1949) "Our National Economy's Dependency on the Overseas Products"; *ibid* (1949) *Preface* (see also Supreme Commander for the Allied Powers, General McArthur's letter to Prime Minister Shigeru Yoshida, purporting to notify *the Nine Principles of Economic Stabilization* (General Headquarters, the Supreme Commander for the Allied Powers (1948))); The Ministry of International Trade and Industry (1974) *Conclusion, White Paper*; *id.* (1980) *Conclusion, White Paper*; *id.* (1990) 1.3.3; *id.* (2003) 4.1.3.1; The Ministry of Economy, Trade and Industry (2009) 3.1.1; *id.* (2011) 2.3. Business and political leaders have not explained how the Japanese industrial structure have highly depended on import from overseas for energy.

¹³ The Industry Planning Commission, a private think tank presided by Yasuzaemon Matsunaga, a founder of nine electric companies, and constituted of some leading heavy chemical industry company executives and some influential Liberal Democratic Party members, issued in 1958 the sixth recommendation entitled "A Wrong Energy Policy", purporting that because it was high-priced domestic coal products that raised the cost of highly competitive export products in Japan and because an excessive quantity of oil was supplied at a

administration to be disengaged from the pre-war military expansionism and participate in international division of labour¹⁴, Japanese people have been collectively committed to developing heavy chemical industries and trading their products internationally, in order to secure their own food and resources in the international division of labour. Under that collective commitment, their land resources have been exhaustively exploited for higher transport and communication efficiency in land and sea¹⁵. Thus the self-belittling attitude or growth-supremacy has led Japanese people to commit themselves to heightening material international interdependency, thus seeking for the self-sufficiency in food and energy among more than one country. However, at least the leaders' mentality whether conscious or subconscious, especially in the post-war first few decades, is not very different from the forefathers¹⁶.

6. The Japanese Pre-War Political Discourse of Self-Belittling

The political leaders of the newly established Meiji regime, who, born of the lower or middle military class from some powerful local feuds, had revolted against,

much lower price by Arab countries, the government should lift the protection of domestic coal production and import oil from overseas without tariff. The recommenders were trying to make a rational decision, considering the world economic situation after the Second World War. Their recommendation was politically influential on the Japanese energy transition from coal to oil. While labelling the government's protectionism as "isolationism" 「孤立主義」 and "claim to self-sufficiency" 「自給政策」 (5), they argued from the proposal that modern industry and social life were run by mass energy consumption and that their quantitative development was not without more of the consumption (18). They were not committing their proposal to further analysis. This attitude suggests that the government and most of the policy makers at that time would have shared the assumption. See also the Industry Planning Commission (ed.) (1958), *Appendix* 'The Basic Problems of Our Country's Energy Policy'. Also, the fundamental policy of securing energy resources in conjunction with the development of industries was already suggested in the beginning of Japan's nuclear energy policy in the 1950's (see Article 1, Basic Atomic Energy Act, (1955); see also Atomic Energy Commission (1956)). The top objective for the civil utilization of nuclear energy, decided by leaders in the political, business and academic world in 1954, was to secure energy supply in the future (see The Atomic Energy Utilization Research and Preparation Committee (1954)).

¹⁴ The US occupation policy under Government and Relief in Occupied Areas (GARIOA) in effect changed from the de-industrialization, to the economic reconstruction, of Japan, in so far as Japan participated in the international division of labour (see Article 14, San Francisco Peace Treaty 1951 and Prime Minister Yoshida's speech at San Francisco Peace Conference on 7th September 1951). General McArthur, Supreme Commander for the Allied Powers, sent to Prime Minister Shigeru Yoshida on 19th December 1948 a letter on the principles of the Japanese economic stabilization. His text on behalf of the United States of Government, quite politically influential in leaving the government and the nation no room of the right to self-determination and in effect leading Prime Minister Yoshida to dismiss the Diet session the next day for the overall renewal of the government's policies, showed the directive addressed to the Government and the nation of Japan, saying in a threatening tone "If [the objectives herein stated are] not [accomplished], Japan shall fall into ruin." However, in requiring for the economic independence, not termed 'self-sufficiency', by increasing production and promoting exportation, McArthur presupposed, whether in the sense of a short or long term, that Japan was in shortage of food and resources, which retrospectively seems to me to have authorized Japanese policy makers' public reference thereafter, unlike the two preceding prime ministers, to a negative and belittling view of Japan's land and resources, implying a negative view of collective self-sufficiency.

¹⁵ The Economic Planning Agency (1962); Tanaka (1972); Shoji and Miyamoto (1964); id. (1975); Hanayama (1978) 1-52.

¹⁶ As Prime Minister Yoshida's speech at San Francisco Peace Conference on 7th September 1951 did not avoid implying, the government of Japan in the post-war restoration did not abandon the go-beyond policy but acquiesced in mitigating the policy under the de-militarization of the 1946 Constitution or pursuing it within the limits of the frame of "world democracy and world freedom" (Yoshida, S. (1951)).

and defeated, the Tokugawa military regime, could not find any motivation to continue to stop pursuing nationally a military expansionism formerly long reticent in the local military feuds¹⁷. Through the two wars against a single nation, the Sino-Japanese war and the Russo-Japanese war, a self-belittling attitude was deeply rooted in the politico-military leaders but it gained more moment after the First World War as they became more aware that they had to prepare for total warfare. This attitude permeated many other people in society too¹⁸.

The cause of expansionism, as always, was “defence”¹⁹ but in the primary sense, not of individual community members but of “country” *kuni* 国 or “country-family” or “state-as-family” *kokka* 国家, both ideas, although usually used as the translation for a country, a nation, or a state, yet in this context totality in the abstract. For that cause the political and military leaders and the subordinates planned to mobilize every human and material resource available merely as means²⁰, and specifically to seek for the full self-sufficiency by

¹⁷ Some revolutionary militant leaders already proposed an expedition to the Korean Peninsula, Sakhalin, and Taiwan even before the revolutionary war ended (Ohyama (1978)). See also the reports drafted by Aritomo Yamagata (1838-1922), field marshal and twice prime minister, most influential in forming the political administration and military force of the Empire of Japan: Yamagata (1871; 1880; 1882; 1890); for Lorenz von Stein’s theory, influential over Yamagata (1890), see Kato (2002) 82-97; for the 1907 national defence guideline of the Empire 「帝国国防方針」, earlier drafted by Giichi Tanaka and revised by Yamagata (quoted by Shimanuki (1973)): “Article 1: The Imperial policies have been conducted in accordance with the country’s principle enacted at the beginning of the Meiji era, “Open the country and make progress” [開国進取], and, no doubt, never in disaccord; so that more in accord from now on shall the country’s proper claim [国権] be urged to be to more interests and the national welfare, to be higher; hence, if the country’s claim be willed to more interests, and the national welfare, higher, then, whereas many regions of the world are to be managed, *both* the concessions at Manchuria and Korea, which, in the war waged in the 37th and 38th years of the Meiji era [the Russo-Japan War], had been gained at the sacrifice of tens of thousands of live spirits and an enormous amount of goods, *and* the development of civilian powers in South Asia and on the other side of the Pacific Sea, shall, among all other regions, be protected, not least, enlarged; that is what must be the greatest of the Imperial policies; therefore the national defense by the Imperial force shall be designed on the basis of the fundamentals of the country’s policies; in other words, another country if it intends to infringe on our country’s proper claim, and if it is placed at least in East Asia, shall need be committed to our aggression; . . . Article 3: Considering the Imperial military history, the principle of retrogression has, from the ancient times to date, been devoted to only by the Tokugawa regime; no others have refused progress [進取]; that is, recently, in the wars waged in the 27th and 28th years [the Sino-Japanese War] and in the 33th year and in the 37th and 38th years of the Meiji era, a great victory was won by electing the policy of aggression; this history obviously demonstrates the Japanese collective characteristic; hence, if the time should come when there is no choice but to take arms, this characteristic of ours could not but be relied on; on balance, the chances are slim that any tactics disagreeable to a nation’s characteristic has gained much.”; see also Kurono (2002) 26-38.

¹⁸ In the middle of the Sino-Japanese War (1894), Soho Tokutomi 徳富蘇峰 (1863-1957), converted from a democratic pacifist, already proposed that the go-beyond policy was originated from the opening of the country 開国 in the final decades of the Tokugawa regime (Tokutomi (1894) 84-85).

¹⁹ The government administrators, when they decided to invade Taiwan, had intended to *defend* Japan (*The Protocol on the Action against the Indigenous Tribe in Taiwan* (1874)).

²⁰ As early as in 1874, seven years after the Meiji Revolution, the nation’s need for coal, iron and oil was made clear by K. Otori (1879), a former Tokugawa shogunate military strategist and later a Meiji regime governor of Hokkaido Development Bureau, in his handbook on the utilization of coal. The text implies that a policy maker understood that the primary energy for the nation’s economy had shifted from rice, wheat, cotton, hemp, wood and rock to coal, iron and oil and that because of the wants in coal, iron, and oil, the region the newly-established government ruled was to be developed by their exportation. The specified scientific arts in that handbook also imply that the government was intending to develop their nation by transforming the phenomenal world materially and

unilaterally expanding the territory and intra-communalizing some other communities²¹ (see Graph 2 in *Appendix*). This mentality had been fostered not only in the newly-established modern education for the civil and military high-rank officers²² but also in the tradition of Buddhism and Shintoism. Japanese intellectuals, policy-makers and policy-drafters, mentally committed to the Japanese Buddhism or Shintoism or their mixture under the influence of the Tendai School might have tended to idealize things in the sensible world, following the indiscrimination in Buddhahood in the super-sensible world²³ but at the same time, because of such idealism, also might have ignored the effect of their real and concrete degeneration they committed²⁴.

7. The Potential Self-Belittling in the Tokugawa Era

As argued before, people were totally self-sufficient in food and energy inside the area the Tokugawa regime governed in the Japanese archipelago but as the ruling military non-producer class forced the hamlet producers in trades called *hyakusho* 百姓, mainly composed of the farmers, to tribute, in the total of each hamlet, not individually, their products and resources, so the hamlet elders led the community members to exploit their own land resources as much as possible²⁵. Hence, although the earlier ideologists attributed the legitimacy of the Tokugawa regime to ‘natural order’, an unalterable and uninvented law behind the sensible world²⁶, the ruled farmers as well as the ruling militants were committed to

spatio-temporally by means of the Western science and technology. See also a policy maker’s explanation for public infrastructure improvement work national bond, 1878 (quoted in Sakano (2009) 35).

²¹ E.g. Kuniaki Koiso (1917), *The Imperial Defense Resources* 『帝國国防資源』 (quoted by Kuzuhara (2001) 37): “Our country’s best policy in between wars is to gain superiority in raising the most necessary resources for the independent war-conducting economy both by developing domestic industry and by utilizing and exhausting the resources in China.”

²² For the education for the civilian high-rank officers, see The Commission of the Study on the Pre-War Bureaucracy (ed.) and Hata (1981) 447-657; Hata (2004); Ushioji (1984) 12-14; 126-141; Shimizu (2013) 189-201; for the education for the military high-rank officers, see Hata (1991); Kurono (2004).

²³ Nichiren in his short dissertation entitled *Disputation on Trees’ and Plants’ Attainment of Buddhahood* 『草木成仏口訣』 explores through discussing the presuppositions in the Chinese and Japanese predecessors’ theories of trees’ and plants’ attainment of Buddhahood a fundamental principle underlying the phenomenal world, that is, the ultimate de-differentiating interactivity structurally to precondition our phenomenal distinction between the sentient and the insentient and the activity and the passivity in our practice (Nichiren (1272), *Disputation on Trees’ and Plants’ Attainment of Buddhahood*). Dogen is primarily concerned as Nichiren is, not merely with extending Buddha-nature to trees and plants but with exploring the structure of the ultimate de-differentiating interactivity preconditioning the contradistinction in the phenomenal world between the subject and its objects.

²⁴ Buddhist moral philosophers have repeatedly argued about human beings’ ordinary destruction of trees’ and plants’ life (see, e.g., Maeda (1996) 36-39; Watanabe, Y. (2000) 14-15).

²⁵ Watanabe, T. (2013) 53-92; 209-258.

²⁶ Maruyama (1952), *Postscript*, 369. See also *ibid.* 208.

expanding their given limits in their technological and feudal conditions in order to secure the continuity of their idealized family²⁷.

8. The Expansionism in and before the Inter-Local-Powers Warring Era

The Tokugawa nationwide regime succeeded the previous Hideyoshi nationwide regime's demilitarization of hamlet farmers but local militant powers before had been warring against their neighbours for nearly a hundred years. The military and political leaders exploited and mobilized, for the security of their idealized family, the resources and manpower in the area they governed²⁸. This policy can be traced back to the Shogunate commissioned military collector's management of the local community and further back to the tenth century locally deployed military commander-in-chiefs' transaction with local soldier-and-farmers²⁹. Perhaps, the potency to expand the given limits for food and energy security germinated in the storage economy in the age of hunting and gathering³⁰.

9. Ethical Implications of the Collective Self-Belittling Attitude

On the historical sketches proposed above, I hypothesize that in the Japanese archipelago the political and/or military leaders and the ordinary people following them have been committed to belittling their given life conditions (thereby mistaken in their true self-sufficiency) and expanding their limits for the cause of their security. Since the idea of self-belittling is illusory, the moral principles from that idea are also illusory. Hence, the policy of unilaterally intra-communalizing some other communities beyond one's own boundaries may increase the total benefit of one's community members or secure the community's

²⁷ Watanabe, T. (2013) 98-102; 263-265; Nishikawa (1977-78). See also Joshin (Shigemasa) Miura 'Of the tiding that gold miners have been found in countries', *Keicho Era Tidings*, vol. 7 三浦浄心 (茂正) 「諸国に金山あること」『慶長見聞集』(富山房 袖珍名著文庫 巻25) 巻7; *ibid.*, 'Of the tiding that His Excellency has built the town of Edo by burying the sea in the south' 「南海を埋め江戸町立て給ふ事」.

²⁸ Toshikage Asakura's *Seventeen Codes*, 16th century; Article 30, *The Imagawas' Formularies in Syllabary Characters*, (16th century); Article 17, *Announcement of the Codes in Kai Country*, in: *Koyo Gunkan (Militaristic Instructions in Kai Country)*. *Jin-Kai Shu (Dust and Dirt Collection or A Collection of Codes)* 塵芥集 (1537), 222 (see Text 44); 'The Codes Promulgated on the Venerable Shrine Kaito' *The Will of Suenaga Takezaki* (1293), 374; *The Will of Seishin Hayaki*, 378.

²⁹ Article 3, *the Adjudication Codes* 御成敗式目, promulgated in 1232; *Codes over Local Wrongdoings*, promulgated in 1346; Article 36, Article 38, and Article 43, *the Adjudication Codes* 御成敗式目.

³⁰ Testart (1982).

continuity. Bilateral intra-communalization between two communities based on all the individual members' agreement or some inter-agreed collective decision process such as referendum may be ideally preferable for the total self-sufficiency the two communities enjoy; and resultant discriminations in some aspects such as economy may be committed to further democratic revision. However, a practical bilateral or multilateral economic interdependency through the mechanism of the market economy in the real international politics is still problematic for the reason that (1) the existent economic discrimination both international and domestic remains and perhaps, as a result, degenerates; (2) the policy decision process is not necessarily fully known or open to the vulnerable. Surely, the bilateral international agreement may undergo revisions and modifications in the practical democratic process. However, the bilateralism or multilateralism, however realistic in the real international political negotiations, could only secure the self-sufficiency limited to the people concerned. Such a limited self-sufficiency policy, if distributive inequity were left outside the newly-created community, would be morally a kind of collective egoism. Hence, if the distributive equity every individual of humankind benefits from were to be pursued, a limited self-sufficiency policy should be added to by the practical process for the realization of such a global distributive equity. Therefore, one who is living in a local community in the Japanese archipelago should pursue a democratic process conducive to such global justice by disengaging oneself from the collective commitment to the belittling of the country Japan. Otherwise one could not disengage oneself from exploiting the community resources and humanity for the idealized totalitarian idea of country or nation and in truth deteriorating one's own life conditions.

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Appendix: Tables and Graphs on Japan's Pre-War Time Self-Sufficiency in Resources

Table 1: The Pre-War Cereal Production and Population

Year	population (1000 people)	rice (1000 koku)	barley (1000 koku)	wheat (1000 koku)	rye (1000 koku)	barley, wheat and rye (1000 koku)	Cereals (1000koku) (rice,barley, wheat and rye)
1880	36649	31434	5824	2266	4413	12503	43937
1890	39902	43038	5420	2460	2843	10723	53761
1900	43847	41466	8667	4256	7433	20356	61822
1910	49184	46633	9291	4602	6718	20611	67244
1920	55473	63209	8290	5891	8297	22478	85687
1930	64450	66875	5141	5589	5631	16361	83236
1940	71933	60874	5451	11948	5797	23196	84070

Note 1: All the statistics are those of the Japanese Islands, and do not include those of the area the pre-war regime ruled, Taiwan, the Korean Peninsula, or Manchuria.

Note 2: The statistics of the population is quoted from Yano Tsuneta Memorial Foundation (ed.) (1981), *Japan's One Hundred Years as Figures Show It: The Chartered Statistics of Japan in the Long-Range Statistics Edition* 『数字でみる日本の百年 日本国政図会 長期統計版』

Note 2: Of the production of the cereals, rice, barley, wheat and rye, measured by the koku, the statistics from 1880 to 1920 is quoted from Asahi Shibun (Asahi Newspaper Company) (1930), *The Statistical Conspectus of Japan's Economy in the Meiji and Taisho Eras*, 2 vols 『明治・大正期 日本経済統計総観』2巻 (reproduced in 1999); the statistics from 1930 to 1940 are calculated from the statistics by the ton in The Statistics Agency, Bank of Japan (1966) *Our Country's Primary Economic Statistics Since the Meiji Era* 『明治以降 本邦主要経済統計』 (reproduced in 1999).

Table 2: The Annual Cereal Consumption per Person by the koku

	rice (koku)	barley and rye (koku)	wheat (koku)	total (koku)
1912-1916	1.060	0.343	0.105	1.508
1917-1921	1.133	0.302	0.143	1.578
1921-1926	1.127	0.256	0.151	1.534
1927-1931	1.106	0.223	0.145	1.474
1932-1936	1.067	0.187	0.127	1.381
1937-1941	1.074	0.179	0.124	1.377
1942-1945	0.950	0.131	0.116	1.197

Note 1: The statistics are quoted from Table 1, Masanobu Yamashita (1956) 「戦前、戦後における農家の食糧需要構造の変化と原因」 (‘The Change and Cause of the Structure of Food Demand in the Farmers’ Households in the Pre-War and Post-War Time’) 『食糧管理月報』 (*Food Control Monthly*)8: 68-71.

Graph 1: Self-Sufficiency in Food as Approximatel Measured by the koku worth the Annual Food Consumption of an Adult

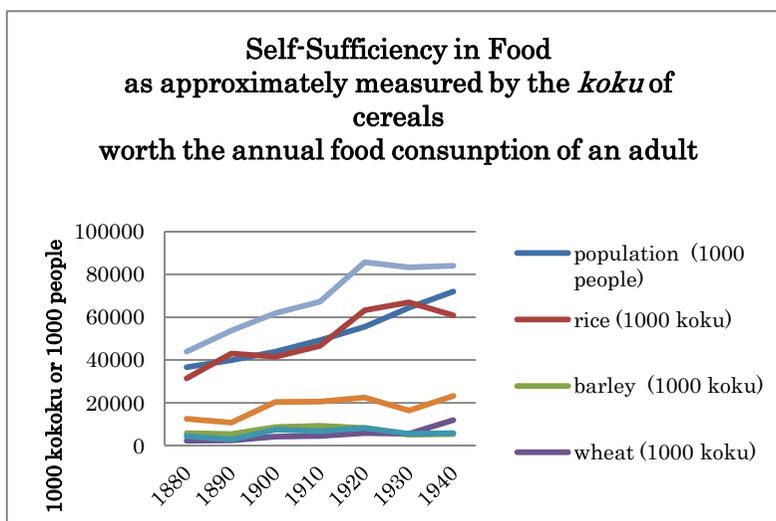


Table 3: Self-Sufficiency of Rice

Financial Year	Domestic Production	Import	Domestic Consumption	Self-Sufficiency
1911-1915	7376	526	7836	0.94
1921-1925	8535	1212	9612	0.89
1930	8704	1259	10073	0.86
1935	7759	1953	10566	0.73
1939	9863	1471	11884	0.83

Note 1: The statistics of Tables 3-6 are made from the data in Tables 5.19-22, Yano Tsuneta Memorial Foundation (ed.) (1981). The original tables, the editor notes, are made from The Ministry of Agriculture, Forestry and Fishery, *Table of Food Demand and Supply*.

Note 2: The domestic production, import, domestic consumption in Tables 1-4 is calculated by the thousand ton.

Note 3: The figures of the financial year period 1911-1915 and 1921-1925 in Tables 1-4, although the editor makes no notes, are the average figures per year, I conjecture.

Note 4: The self-sufficiency of the items in Tables 2-5 is a quotient resulted from the division of domestic consumption by domestic production.

Table 4: Self-Sufficiency of Wheat

Fiscal Year	Domestic Production	Import	Domestic Consumption	Self-Sufficiency
1911-1915	663	103	743	0.89
1921-1925	743	519	1193	0.62
1930	838	693	1247	0.67
1935	1321	421	1375	0.96
1939	1657	171	1283	1.29

Table 5: Self-Sufficiency of Beans

Fiscal Year	Domestic Production	Import	Domestic Consumption	Self-Sufficiency
1911-1915	437	312	746	0.59
1921-1925	483	553	1029	0.47
1930	340	612	949	0.36
1935	275	650	921	0.3
1939	343	779	1118	0.31

Table 6: Self-Sufficiency of Potato

Fiscal Year	Domestic Production	Import	Domestic Consumption	Self-Sufficiency
1911-1915	786	0	775	1.01
1921-1925	939	0	931	1.01
1930	1037	0	1017	1.02
1935	1250	0	1202	1.04
1939	1883	0	1846	1.02

Table 7: Self-Sufficiency of Petroleum

	Domestic Production	Import	Dependency on Import	Self-Sufficiency
1888	13	no data	no data	no data
1920	352	no data	no data	no data
1930	317	570	64.3	0.36
1935	351	1332	79.1	0.21
1940	331	2292	87.4	0.13

Note 1: The statistics of Table 7 are made from Table 4.25, Yano Tsuneta Memorial Foundation (ed.) 1981, op. cit. The editor notes that the original data are quoted from The Ministry of International Trade and Industry, *Annual Petroleum Statistics Report*; id., *Annual Energy Statistics Report*; id., *Annual Energy Production and Demand Statistics Report*.

Note 2: The domestic production and the import are calculated by the kilolitre.

Note 3: The dependency on the import is indicated by the percentage of the import to the domestic product and the import.

Note 4: The self-sufficiency is a quotient resulted from the division of the domestic product by the domestic production and the import.

Table 8: Self-Sufficiency of Coal

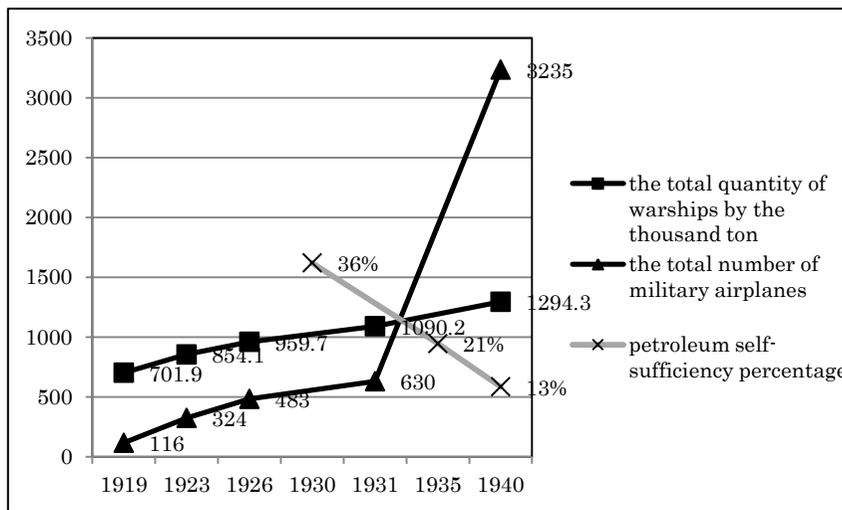
	Domestic Production	Import	Demand	Self-Sufficiency
1926	31424	2414	34230	0.92
1930	31374	2946	34277	0.92
1935	37762	5249	43315	0.87
1940	57318	9896	67207	0.85

Note 1: The statistics of Table 8 are made from Table 4.19, Yano Tsuneta Memorial Foundation (ed.) 1981, op. cit. The editor notes that the original data are quoted from The Ministry of International Trade and Industry, *Annual Coal and Cokes Statistics Report*; id., *Annual Energy Statistics Report*; id., *Annual Energy Production and Demand Statistics Report*.

Note 2: The domestic production, the import and the demand is calculated by the kiloton.

Note 3: The self-sufficiency is a quotient resulted from the division of the domestic production by the domestic product and the import.

Graph 2: The Pre-War Time Military Power Growth and Oil Self-Sufficiency Decline



Note 1: The statistics in this table are calculated on the basis of the data given in Table 10.1, the Yano Tsuneta Memorial Foundation (ed.) 1981, op. cit. The editor notes that the original data is quoted from The Cabinet Secretariat (ed.), *The Seventy Years' History of the Cabinet System*.

IX. Folkloristics

A Folkloristic View of the Japanese People's Perception of Nature through a Collective Idea of Animals in Some Trans-Special Matrimony Folklores³¹

Mitsuo Namoto (translated by A. Taki)

1. Introduction

The humans have acquired unprecedented material prosperity with industrialization as a stepping stone whereas they have allowed the accumulation of environmental problems such as environmental pollution, environmental deterioration, resource shortage, the population problem, the North-South problem and so on.³²

As these problems loom more serious, people today have been trying to find in the interrelation between humans and nature in traditional societies a clue to what attitude to take toward nature in the future. Furthermore, they have been more interested than before in the people living in the traditional societies, for example, how they utilized nature, what their daily living was, and what local culture they formed. To sum up, how people in the past perceived their surrounding nature has become a great concern of people living today.³³

Against the background of such actual concern among people today, I will, in what follows, explore, especially by focusing on folklores of trans-special matrimony between humans and animals, how people living in the Japanese islands have perceived nature.

Folklores, since they are recited among people as orally transmitted literature, are transmitted only if in accordance with the values and the world views in a local society where they are transmitted and if not, either brought into

³¹ 名本光男「異類婚姻譚に見る日本人の自然観について—日本人は動物をどのように見てきたか—」, Namoto Mitsuo (2010), 'Inui-Kon'in-Tan ni Miru Nihon-Jin no Shizen-Kan nituite: Nihon-Jin wa Dobutu wo donoyoni Mitekiaka', Faculty of Social and Environmental Studies, Josai International University, *Bulletin*, 19-7, 33-44.

³² Kakeya (1990:281).

³³ Matsui (2000).

oblivion or transformed into a tale in such accordance.³⁴ And once in oblivion, a folklore, just under oral transmission, is never succeeded by the following generation.

In contrast, once accepted in a local society, a folklore continues to include lessons for the local living.³⁵ Specifically, the audience, while repeatedly told who becomes happy, who meets a miserable end and what they have done for their results etc, are expected to inscribe in the heart of the mind, and conform to, the impregnated values and worldviews,³⁶ whereas the storytellers work to continue to reconfirm the values and worldviews of the local society.³⁷

For these reasons one can justifiably assume that if one scrutinizes tales in which animals behave one can find there what animals were for the people interacting with the animals, and thereby, what nature was for them, and therefore, how they thought they should behave toward animals and nature.

2. Folklores with Reverence for Nature

Among all the folklores transmitted in Japan to date, there are animal tales, the tales in which animals appear and they are recorded all over the country. All the animal stories tell that animals described there lead a life as we humans do, interact with us as if they were our co-habitants living in the world shared with us, and are very often benefactors, as described in the *Shitakiri Suzume* (*Tongue-Mutilated Sparrow*) or the *Tsuru Nyobo* (*Crane Mistress*), who will do us affluent favors if we do not even go wrong in contacting them.³⁸

³⁴ Kawamori (2000: 12-18) wrote that folklores, censored by what is called an ethnic society, which, though relatively closed, maintains its own social tradition, are sometimes accepted and sometimes deleted.

³⁵ Folklores include elements suggesting lessons because they are to fulfill the requirements of the ethnic society (Ozawa (1974: 35-55)).

³⁶ In a society adults take the role of arranging that children's behavior conforms to the society's expectation. This role is called canalization (Bock (1977: 142)).

³⁷ According to Sakurai (1996: 49), because a folklore is "an inheritance arising and growing in the life of the whole of a race, the way of living they have cultivated and their view of life or the world reveal themselves spontaneously there; that is, in the deepest layer of the world a folklore describes, the race's historical, social and spiritual background runs." And among the *Ainus* myths have the same function as folklores do. The *Ainus* learn from myths how to behave in the world and "from where happiness or unhappiness arises, and how one can evade unhappiness" (Nishida (1989: 82)). What is the difference between myth and folklore is challenging but admittedly they are similar in that they include how to behave in the daily life.

³⁸ Of the conditions of those who provide affluence, Onuki says (Onuki (1995): 122), "They must be visitors from the outside, often in disguise of animals and residents in the outside of the village, sometimes in the sea and at the bottom of the swamp and sometimes deep in the mountains" whereas, of those who are offered affluence,

In contrast, if one is arrogant toward animals or deceives them, those stories tell, he or she usually will meet a miserable, and even atrocious, end, as the old woman who deceives a sparrow does in the *Shitakiri Suzume*.³⁹

Interpreted in the symbolical topography of Japan, the mountain area which wild animals inhabit, far away from the human resident area in the countryside, is the area where divinities preside; in addition, a sparrow as in the *Shitakiri Suzume* and a crane as in the *Tsuru Nyobo* are mountain resident divinities themselves or their heralds. In folk beliefs, those who grant us affluence are visitors from the outside, that is, divinities resident in the mountain and the water far away from the human resident area.⁴⁰ Komei Sasaki, Japanese folklorist, says in his thesis that people have believed that the mountain divinity rules the whole of the mountain and that under its rule and auspices they are working and living in their daily life, and in conclusion also says that people have fostered the view of nature and religion in which they awe and revere the divinities, believing the mountains as their residence and worshiping those mountains.⁴¹

In accordance with those scholarly views workers active in the mountain area actually believe that the divinity resides deep in the mountains and conduct a variety of rituals.

For example, a mountain worker called a *matagi*, who lived by hunting animals, especially bears, deep in the mountains, showed his reverence to nature, saying about bears living all the year in the mountain, “[Bears live (bracket Namoto’s)] nearest to the mountain divinity among the mountain beasts, wiser in the mountain than humans. ...They have the power to survive in nature on their own. That’s stunning!”⁴²

Those who used to interact closely with the mountain believed that animals were very cordial fellows living in the same community and that they were to be respected because they were gifted with the capability of living in nature all through their life.

“They must be honest, piteous toward animals, or among all other characteristics, good-natured, for which affluence offered is a reward.”

³⁹ Seki (1988: 72-76).

⁴⁰ Onuki (1995: 123-124).

⁴¹ The mountain divinity is a productive one that is committed to a variety of works and activities conducted in the mountains, according to Sasaki (1993: 258).

⁴² Taguchi (2001: 156).

From these actual mountain workers' recorded words, one could justifiably assume that our ancestors kept in close relationship with nature and animals and the divinities' resident area. On this assumption one could also explain why animals in folklores are described as very close to us.

Kunio Yanagida, folklorist in Japan, in his work entitled *Life in the Mountain* enumerates a number of cases that people keep their livelihood in the mountain, one of which is a story of a boy protected under the custody in *Soshu* (Kanagawa Prefecture today (bracket the translator's)). Yanagida describes of his life, "He is not in the shortage of food all the seasons: in spring he eats a variety of tree shoots row while in winter he eats grass roots he digs out. Some of them taste good. As it becomes cold, he patches leaves with a small animal's skin for his clothing. ..."43

Uchiyama, Japanese philosopher, reports that in a Gumma Prefecture mountain village where he lives, there used to be customs called "*Yama Agari*" (*Going up the Mountain*), according to which when a villager was reduced to poverty by a debt or something like that, he went up the mountain and lived there for some years while some capable member in his family went to town to find a job and paid the debt; and the debt settled, he came down to the village and retrieved the original life.

If you do not keep your household in nature, you might critically regard the customs *Yama Agari* as a miserable escape from the debt collector but villagers have found his temporary mountain life amenable, Uchiyama reports. People at that time, when they went to the mountain, were capable of cutting down a tree and instantly building a hut. Every one had skills and wisdom by which to utilize the benefits from the mountain.⁴⁴

I can hardly identify at what chronological time in the past these cases were but in so far as I interpret the cases collected at least in folkloristics, I have good reason to conjecture that people living in the past, since they utilized mountain resources widely in their life, found mountains to be an area more familiar than people living in modern life.

3. Folklores with Betrayal to Nature

⁴³ Yanagida (1968: 61).

⁴⁴ Uchiyama (2005: 36-38).

In most of the Japanese folklores, as argued before, the main human character gains riches because he or she is kind to the animal character contacted. However, in some of them, despite being very cruel to the animal character, the main human character becomes happy.

Let me take *the Macaque Matrimony* for example. This folktale begins with an old man at a loss for the completely dried rice paddy spreading in front. His family's downfall looms with no water to be let in and therefore no young plant to be transplanted in the paddy. A macaque spots and comes to the poor old man. He proposes to marry a daughter in reward for water irrigation. The old man jumps at the offer. The macaque lets in water all over the vast rice paddy and marries in reward the youngest daughter of his. He returns home with her.⁴⁵

The story makes a turn, however. Three days after the marriage the macaque is very kind to offer to visit the old man with her. Asked what is the gift she recommends, the wife proposes a rice cake he pounds in the mortar. The macaque faithfully follows her recommendation and starts for the old man's home bearing a heavy mortar on the back. When they go by a valley, the wife asks for a pretty flower. He climbs up to the end of a thin branch until the branch breaks and he falls down to death at the bottom of the valley.⁴⁶

Folklorists have read in the *Macaque Marriage* a lesson that one cannot forget the austerity of the past agriculture that forced farmers to request for help from the last one they wanted to request, that children must devote themselves to their parents even by sacrificing themselves, and that one can never be happy without devoting oneself to one's parents.⁴⁷

However, compared with the other animal folklores transmitted in Japan, it is rather extraordinary that an innocent macaque is deceived and at last killed by a human young wife who marries him in accordance with the contract that one of the daughters shall be married to him on condition that he irrigates water to the dried rice paddy for her father. The young woman, the story goes, leads a happy life in the end, as she should not in the other folklores. She should pay a divine punishment in a normal folklore.

⁴⁵ The macaque appearing in front of the old man is a superman or some one belonging to the world of the others than humans, such as divinities and monsters; in other words, the macaque is, one can reasonably say, a resident not in the human world but in the other world (Komatsu (1985: 149)).

⁴⁶ Seki (1988: 72-76).

⁴⁷ Komatsu (1985: 144).

Why should the young woman kill the kind and good-natured macaque? Komatsu explains the reason as follows: “The story suggests to the audience the firm bond between the old man and his daughter. The bondage furthermore implies the bondage among people in the human world in general, which the folklore under discussion implies is in opposition to the equivalent exchange between the worlds of the human and the other species, that is, between labour in the paddy and a woman. ... The reason that the youngest daughter despite the two elder sisters’ refusal willingly accepts the father’s request is no doubt the pleasure in rescuing, and devoting herself to, the parent, not in marrying a macaque. ... Here the structure of the story with respect to the relation between the other species’ and the humans’ worlds shifts from the relation between the macaque and the old man to the matrimonial relation between the macaque as husband and the youngest daughter as wife. The youngest daughter, dissatisfied with the position of a macaque’s wife, attempts to evade her husband. At this point, the focus of the story shifts from the matrimonial relation to the rivalry in shrewdness, and specifically, a husband’s stupidity and his wife’s shrewdness. This opposition is transformed into the opposition between the bad in stupidity and the good in shrewdness, that is, the opposition between good and bad [according to the standard in the human world (bracket Namoto’s)]. Therefore, as is a necessary consequence of the story, the evil is extinguished whereas the good wins (*i.e.*, the good gains life).”⁴⁸

However, is it not that people living in Japan used to extend pray, awe, thanks to nature and cohabit with nature, as shown in the folkloric testimonies recorded in Japan? And is it not that as described before, the *matagis*, who kept their livelihood by moving swiftly in the mountain and hunting animals, never believed that animals were stupid or unwise?

In addition, mice, macaques and sparrows, very often appearing in folklores, the so-called the other species, are never described as evil. Good-natured old men, many of the animal folklores represent, are always sincerely kind to the other species and the latter do good in reward to the former and everything goes well.

All the same, it is the brutal fact that the *Macaque Marriage*, a story, despite with a cruel betrayal to nature, telling at the end “They lived happily ever after,” has been transmitted widely in our country.

⁴⁸ Komatsu (1985: 151-154).

How could one consistently interpret Japanese people's view of nature presupposed in the two types of the Japanese animal folklores, one with reverence for nature and the other with betrayal to nature?

Let me begin, as a clue to the problem, with a villager's story of rice paddy culture I heard during my enquiry survey conducted in *Tsugaru* District, the northeast area of Japan. It runs: "The most important work at the beginning of rice paddy cultivation in spring is to separate distinctly the *kuro* of the rice paddy." The *kuro* is a division and path between rice paddies. The work is to cut with farming implements such as a spade or a cutter called *tachi* a trench as deep as possible between the areas for cultivation and for *kuro*. The villager adds, "The rice paddy comes to be separated from the surroundings and as a result, weeds can hardly enter the rice paddy." In my research paper at that time I wrote, "The villager's testimony implies that the spring initial work aims to distinguish between the rice paddy and the weeds, that is, between artifice and nature. That is an expression of the relation between the human and nature in our country, I propose."⁴⁹

Still now I hereby propose again as a clue to the present problem that there exists a certain "trench" between the human and nature in Japan although animals are described as people's co-habitant mate in many of the folklores. I will argue for this proposal in what follows.

4. *The Crane Mistress*, a Folklore with the Animal's Politeness toward the Human

Let me restart with a typical animal matrimony folktale with an opposite ending, *the Crane Mistress*, for the purpose of reconsidering the relation between the human and the animal, and furthermore, the background against which both *The Macaque Marriage* and *The Crane Mistress* are transmitted in Japan.

The Crane Mistress, a story of a rescued crane's requitement by both marriage and texture weaving has become one of the most popular folklores in Japan since the dramatist Junji Kinoshita adapted the original folklore to a

⁴⁹ Namoto (2005: 172-173).

folklore drama entitled *the Yu-zuru (Night Weaving Crane)*. It is transmitted widely in Japan with one hundred and ten versions recorded at present.⁵⁰

The story begins with the scene in which a young man, hurrying home to celebrate the New Year Day, meets a band of people in a brawl over a crane they catch. The young man decides to buy the crane with all the annual wages he gains by hardworking at town. This bird must hold its life dear as he does; its parents must be waiting for it as his parents are for him. Then he lets go off the crane he buys.

The crane rescued by the young man simulates itself quickly into the form of a 'beautiful' woman, visits his home, and persuades him to marry her.

Then, while living decently and happily with the young man, the crane in disguise of a woman, in requitement for his rescue, secretly weaves textiles with the feathers she pulls from the body and arranges that he goes to town to sell her products.

However, these happy days do not last long. The crane, left no means to manage to keep her secret, finally confesses to be the bird he rescues. At last she flies away leaving him and his parents to lament the parting. However, after a full three years of pulling her feathers, she does not have enough feathers to keep flying up in the sky. In the end, all the power exhausted, she falls down to death.⁵¹

This story might sound completely different from the story I discussed before, *the Macaque Marriage*, but these two stories have something in common. That is a trans-special matrimony, the one between the human and the animal as another species.

In the *Macaque Marriage*, a macaque marries an old man's youngest daughter but in this story the relation is inverted. A crane appears to a young man and marries him. On the other hand, the macaque comes near to the human in no disguise whereas the crane steals into the human society in disguise of a human.

In contrast, the macaque in *the Macaque Marriage*, although he helps the old man at a loss and devotes himself to pleasing his youngest daughter as his wife, behaves always in the form of macaque as if he were of the same species as the human. The crane in *the Crane Mistress* interacts with humans condescendingly and politely whereas the macaque, though kind and simple, seems reserved

⁵⁰ Miyaoka (1994: 605-606).

⁵¹ Seki (1998: 201-204).

comparatively too little in entering into the human world. Furthermore, the crane, deplored for her death, is ritually buried whereas the macaque is deceived and killed.

What raises these differences is not directly clear but the key seems to me to be the difference in whether or not animals in the folklores under discussion, when entering into the human world, simulate themselves to humans.⁵² The difference in simulation on the boundary to go beyond, if it were Ariadne's thread, would be traced further into something deepest in the structure, that is, as it were, the collective and fundamental way the ancestors of the Japanese people interacted with animals in the real world.

5. The Interaction between the Realms of the Human and the Animals

Japanese people today are alienated from nature⁵³ but their ancestors as argued before interacted with nature with great awe. They believed that the world inside the mountains was different from the world where they lived. Life and work in such a mountain world forced people to hold an adamant faith and to abide by a highest discipline.⁵⁴

For example, the *matagis*, powerful trailers in the mountain world, are said to make a request for excuse, saying "Please permit me to tread around in your mountain", when stepping beyond the boundary between the mountain and the human resident area.⁵⁵

⁵² N. Kawamori (2000: 32-33) summarises that whereas a hetero-special wife leaves the human world when she betrays herself, a hetero-special husband is deceived and killed in human snares. However, he does not explain why.

⁵³ According to Kawakita (1979: 214), culture lies in between the environment and the humans and is the layers multiply including the humans, composed of technology directly acting on nature to the values and worldview attached to society and the humans. The reason why people living in the modern society have come to find themselves deeply alienated from nature is not only that the humans and nature have been more discriminated in distance but also that the layers of culture have come to be more multiplied.

⁵⁴ There used to be a mark for the division of area by which to separate the area above as the divine world from the area below as the secular world (Obayashi (1983: 47)).

⁵⁵ See Namoto (2005: 179). Hunters living in Village *Akatani*, *Echigo* District, on the mid-coast of the sea of Japan, marked as a boundary between the mountain and the human resident area a small shrine of the mountain divinity on the way and when stepping into the mountain for hunting, prayed for their safety and rich game with a lit candle extended to the divinity; in addition, it was the rule for them to speak in the *mountain* language once they stepped into the mountain area the divinity ruled (Obayashi (1983: 47)).

And once they stepped in, they stopped speaking in their ordinary language, the so-called *plain* or *field* language, *nora kotoba*, and instead began to speak in the *mountain* language. In contrast, when coming back to their resident area, they used only the *plain* language and abhorred the *mountain* language.⁵⁶ If someone mistakenly used the *plain* language in the mountain, he was obliged to purify himself in water.⁵⁷

The evidence for the discrimination in the past mountain workers' language use implies that the Japanese people's ancestors believed that the mountain is a different world from where the humans live. Accordingly, they entered into the different world in order to work *only when necessary* and they did *only to a necessary extent*. In addition, the come-and-go over the boundary was strictly limited. That is how the Japanese people's ancestors interacted with nature.

For example, Chiaki Koike, *matagi* in Yamagata Prefecture, northeast of the Japan main island, said, "In the Miomote hermit, when you hunt a bear, you bring it to the village after you peel its skin and disband its limbs in the mountain. And before you distribute the game, you do *mi-dori*, that is, you scale flesh off the bone. That is the orderings you should keep. According to the mountain codes you shall not bring into the village the whole body of a bear. If it were inevitable, you should make its skin bare or in such disguise. That is the rule. ... Why you mustn't bring in the whole body is because you mustn't do to a bear as you do to the human body. When an accident falls to some villager, his or her body is brought into the village as it is. The rule is also the case with other kinds of the game."⁵⁸

Another example is that people occupied with the field burning as firing work in the mountain, prayed before starting their job to the mountain divinity and conducted a ritual requesting for the permission to utilizing the land.⁵⁹

From these folkloristic cases one can reasonably conjecture that people often perceived the world in the middle of the mountain as the one different from the human resident area. The Japanese people's ancestors would have lived by coming

⁵⁶ The wood-cutters working in the mountain are reported to have used the *mountain* language (Chiba (1993: 173)).

⁵⁷ Among the *matagis* in Nishimeya, Aomori Prefecture, northernmost of the Japanese main island, the filth is purified by sprinkling water over the head with a oval-shaped lunch box called *wappa*, which ritual is called "do a *kori-tori*" (Saito, Makita and Segami (1988: 127)).

⁵⁸ Taguchi (2001: 141).

⁵⁹ Chiba (1983: 202-203).

and going over their boundaries although they were rigorously discriminated as completely different realms.

If this conjecture is right, one could propose a tentative solution to the problem I raised before on the difference between the crane in *the Crane Mistress* and the macaque in *the Macaque Marriage*. For the reason of the above-mentioned transcendence and discrimination in the Japanese people's ancestor's collective and fundamental perception of nature, *the Crane Mistress* had to simulate herself to a human and once she betrayed herself, she had to leave there as quickly as possible. Likewise, Princess *Kaguya* returns to the lunar world and Lady Snow leaves her man. On the other hand, the old man in *the Tongue-Mutilated Sparrow* and *Taro of Urashima*, both travelling in another world, eventually return to the human world.

For the same reason, although in contrast in the story's ending, the macaque in *the Macaque Marriage* had good reason to be killed; he was so simple indeed as to miss the deep "trench" between his and the human world which he should know better than to go beyond.

6. Conclusion

The cohabitation between the humans and nature as Uchiyama, living in a mountain village, describes it,⁶⁰ lasts certainly at the rhythm at which both mutually hearken to each other's breathing.

However, they could both live happily only in so far as they are so discriminated as to abide by the rule of abstaining from entering into each other's world. The macaque, missing the rule, is deceived to death whereas the crane, much committed to the rule, leaves her husband and dies a tragic death but receives reverence in her burial.

Under a closer scrutiny, the two trans-special matrimony folklores proffer a lesson that the animals and the humans, although seemingly living closely in the common environment, yet since in reality living discriminately, should not enter into the heart of the other's world each other.

⁶⁰ Uchiyama (2001).

However, the lesson from the two folklores aside, how people behave toward the animals living in a different world varies considerably among areas and periods.

As the results of an analysis of *the Macaque Marriage* Ozawa answers how the Japanese people used to think of nature, saying, “The folklore implies how much caution they took against the mysterious power rising from the natural environment surrounding them. They demarcated distinctively the boundary between the natural environment surrounding them and their own world.”⁶¹

True, it is the fact that in many of the areas in Japan the Japanese people, mostly farmers long since, have been much concerned to prevent invaders from nature as the surrounding world from plundering their harvest. In those areas, animals such as a macaque in *the Macaque Marriage* and a crane in *the Crane Mistress* would have been those the humans have to absolutely exclude as invaders.

It is also noteworthy that in many areas of Japan the invaders to the local people’s daily life, whether humans from another world or hetero-special living things, have been customarily welcomed as guests, but these customs imply that people have potentially feared them and supposed that if they abuse the invaders they will be retributed by the mysterious powers.⁶² In other words, they are to be interpreted to imply that they subconsciously entertain toward the invaders enmity and intention to murder.⁶³

These hypotheses I proposed above might well explain why Japanese people have exhaustively destroyed and exploited nature since the post-war restoration and the period of rapid economic growth thereafter. They have felt no hesitation. For example, despite that the local forestry culture was radically transformed by completely replacing natural forests with cedars and Japanese cypresses without considering the local biological conditions, local people have felt no remorse. Suppose you have cut down all the forests and left bold hills all around your local area or suppose you have replaced all the natural trees with an artificially designed forest.⁶⁴ There would already have been no such world left as an area alienated from ordinary people where workers, such as *matagis*, who are expert in

⁶¹ Ozawa (1994: 245).

⁶² Komatsu (1985: 71).

⁶³ Komatsu (1985: 71).

⁶⁴ Chiba (1991).

traditional special technique, are only admitted. In consequence, there would be no divinity to worship and no animals to observe carefully and respect. There would not have been nature as opposed to the humans and therefore no obligation to protect nature. This consequence would have been intensified also by the fundamental condition in Japan that the Western conceptual scheme of nature as opposed to the human being has not appeared in the history of Japanese thoughts.⁶⁵

I must here mention in passing an animal matrimony folklore with a trans-special marriage perfected, a tale of the marriage between a killed horse and a girl, reported in Yanagida's *Tono Monogatari (Tales Transmitted in Tono)*.⁶⁶ I cannot discuss its tale in the details but I tentatively add that there can be another tradition in the history of Japanese thoughts in which people living in the area where such a tale is transmitted may perceive animals differently from the people living where the types of folklores I discussed here are transmitted.

In conclusion, the attempt above to deduce from only two folklores what the Japanese people used to perceive nature may sound too foolhardy but I believe that I will fulfill such deduction more profoundly by analyzing against the background of the natural environment, the local works for livelihood and the history in a given local area the values and worldviews inherent in the locally transmitted folklores. This paper, I hope, is the beginning of this future project.

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⁶⁵ Momokawa (1995: 237-238) argues "Since there has been no distinct demarcation separating the humans, the so-called nature as the inner realm, from the natural world, the so-called nature as the outer realm, the idea of nature as totality by which to abolish and comprehend the opposition has not risen" and concludes "If one cannot understand the idea of invention, one cannot understand its opposite idea named 'nature'. Watanabe (1995: 340) says, "The Japanese people, since they have historically long been immersed in nature, cannot clearly distinguish nature from invention, leaving a very ambiguous demarcation between them.

⁶⁶ Yanagida (1968: 30-31).

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X. Carmina Arborea

Trees Talk

Hideko Nameki (translated and annotated by A. Taki)

In mid-October 2013 I was sitting at the open veranda and reading a letter from my professor Taki, when I had long waited for an impetus to prompt me toward writing of my life-long engagement with trees, things I have seen and learned with trees. I had just found it in his letter. Now's the time! The garden looked penetrating in the autumnal air with a faint scent trailing its way, as it struck me, from the chrysanthema.

Nevertheless, a cue comes last after rehearsals beforehand. Queries I can now formulate, even if they had repeatedly occurred to my mind before, might not have emerged in a distinctly crystalized form, if I had not entered the Department of Social and Environmental Studies, Josai International University. I have learned from one of the professors about the conditions of the farming villages in the past we can read from the folklores and elder villagers' stories transmitted in the Togane area; from another the historical role of the Japanese forestry industry and its decline; from a third how the natural-resource-rich area had been preserved near the rural human resident area, what their interaction was, and what we can read from the maps the Imperial Army of Japan composed in the Meiji era, for example, the fields where people used to foster horses in and around the Togane area, the social relations between the former Kawakami Village (Yachimata City at present)⁶⁷ and the former Kohei Village or Takahira Village and the inland trading routes for salt or oranges through the villages. Things I

⁶⁷ According to Yachimata City Home Page, Kawakami Village and Yachimata Village were formed by the governmental consolidation of municipalities in 1889 and consolidated into Yachimata City in 1954; in more detail, Yachimata Village was first formed in the fifth year of the Meiji era, 1872 when Tokyo Prefecture transferred a newly cultivated land to Imba Prefecture; first constituted of Yanagisawa and Omago Pastures, Yachimata Village consolidated Hijikai, Gammaru, Enokido, Ozeki Villages and others in 1889; on the other hand, in the south-west area of the present Yachimata City, ruled by Sakura Dominion and a shogunate vassal in the Edo era, two five villages, Negoya, Okada, Mochikusa, Oyaru and Koyaru Villages and Higashiyoshida, Kami-Isago, Isago, Seta and Yoshikura Villages each formed an association by County and Ward Arrangement Act in the 11th year of the Meiji era, 1878 and then consolidate themselves into Kwakami Village in 1889.

(<http://www.city.yachimata.lg.jp/youran/New/13.html#1> (access: 14th March 2014).

used to learn were dispersed but now have been interlinked thanks to such an immeasurably insightful acquisition in my senility.

One of the riddles previously hovering in the mind had been why matrimony used to be arranged between spouses from the former Kawakami Village and Matsu-no-go Ward, Kohei Village, although there were none of inter-hamlet marriages in Kohei Village. However, I found that a road for the trading of salt used to lead through these two areas. I secretly named the route the Matching Road.

Historically speaking, the former Kawakami Village used to be the feud ruled by Lord Hotta neighbouring on the opposite side of the road *Goryo* Ranch (The Emperor's Ranch), the pasture formerly owned by Lord Nabeshima. The village was the area sold off in the Meiji era for what is called the Meiji reclaimed land. It is adjacent to Kohei Village but there was no exchange in the inter-village level; nor has there been any in matrimony. The reason is, I conjecture, that in contrast with the austere labour in such Meiji reclaimed land villagers in Kohei Village were fostered in the rural area rich in natural resources and that there was no trade in human resources and others between two villages. There used to be a folk saying, "Don't let daughters be sent for matrimony or they will be killed." The pasture area was not rich in woods, water or some other natural resources as in the village-near areas of Kohei Village. There was no rice paddy there.

Gumyo Ward, located in the outermost of Kohei Village, borders the hilly area adjacent to the village. The quality of water in the wells was low. The rice paddies, although located in the swamp, had no canals. Hence the water filling the rice paddies used to be heaven's grace. Water runs from higher to lower places. Severe rivalry among hamlets forbade, and even now affects, inter-matrimony. Until the irrigation canal *Ryoso* was induced, people would have had sufferings in cultivating rice. An old verdict I recently read with a shock in a private archive at the neighbouring ward says, "... There was recently reported to be someone who ran water down toward Gumyo. None shall do that. ...". A slight sign of the past hermit prejudice in the setting of the private exhibition has reminded me how much more rivalry there used to be; still more how deeply where one lived affected what one was and even now.

Fifty years have passed since I came as a bride from the outside to be resident in Gumyo but since I entered the Department of Social and

Environmental Studies four years ago, I have come to understand better how villagers' character has been influenced by the environment they are part of or why they were obstinately attached to the land they were possessed of. No wonder why my eldest son and I were bullied when he was a young schoolboy.

The seasonal harmonies trees played in my home village were not here. There was a slight difference in the green of leaves or the seasonal scents of the village-near hilly nature. In my home village, water rises in the village-near hilly area, trickles through streams, inundates rice-paddies, and flows into the Imba Swamp. There was no rivalry as here. The moment the decade-long riddles were cleared, I told my husband, "Villagers in Gumyo were greatly patient. Your ancestors were honourable." Proffered a nod, I rang the bell in front of the Buddhist altar to pay tribute to the ancestors.

The residents living near the village-near hilly area call the lower rice paddy area in their own terms *shitadori*, meaning literally, *hill-foot gain*. In opposition, the residents living in the lower paddy area call the hilly area in their own terms *yamanote*, literally meaning the hilly area. In my opinion, the latter is where people live in harmony with nature as it is intertwined with four seasons whereas people in the former area are incessantly forced to fight with nature and weather in rice cultivation from young plant implanting in spring to harvesting in autumn.

I would try to retrieve my memory of my home village, where people are wise in exchanging words and thoughts with trees. It was 14th August in the 44th year of the Showa era [1969]. I went to my parents' home for the *Bon*, the dead ancestors welcoming and respecting days, of my dead father for the first time. I was shocked when I looked over the rear of the garden. The Persian silk tree, the only blossom tree planted there, was dead. It was the tree my father had taken care of and liked very well. Things occurred to the tree as I had been told. Elders in an old village used to say that when someone passes away, a tree he or she has taken much care of recollects him or her so faithfully that it follows him or her immediately. When the silk tree began to bloom, my father, reticent though he was, used to praise the blossoms, muttering, "I have seen hardly any such dark colour." Silk trees mostly bloom light pink but the one my father loved bloomed fairly dark.

Looking around, I caught a sight of an *akebi* besides a pine tree. The gardener arranged the *akebi*, a middle-large bowl thick, to my father's pleasure, so that it would train itself on the shelf, nearly a half sheet of paper large, made from

bamboos cut into halves, lessen the number of its blossoms and enrich the fruits it bore. Maple trees there varied in autumnal colour, reddened or yellowed, and in the size of leaves. However, they had been dead except yellowed leaves. Although I have no adequate expression, the rear of the garden had become desolate as a whole. It was dead.

In the front of the garden, some blossom trees and fruit trees such as a *ume* tree, a sweet olive and a cherry tree still stood. However, sometime later, when the main house was rebuilt, the white camellia my father loved, a large sweet olive, a large white *ume* tree, a lying-dragon-postured *ume* tree, a Bungo-make weeping-formed *ume* tree, a yellow maple tree and a formerly two-hulled-boat-shaped boxwood all followed my father.

A garden cannot be given a complete form in a single generation but requires three generations. For the garden's completion not only does the householder have to be akin and generous to trees but also trees have to respond to the householder's attitude.

I have seen here another case of a loved tree's devotion to the dead tree-lover. The *yuki-yanagi*, meaning "snow willow", Thunberg spirea in English, growing in the garden of a house, was splendid. It was one meter fifty-three centimetre high. The blossoms small and white, it stood plying like a willow. When I was attracted by the tree, the householder cut a twig for a gift. When I visited the garden again, however, the tree did not stand there. I asked a son of the householder about the tree. Since his father loved it the tree had died after his death, he replied. "Oh dear, your father kindly cut me a twig around the time I came and marry here." "Gone with my dad." "It followed him. Trees go with their lovers." His father had never cut a twig at any other time. I wondered how inexplicitly I had expressed my wish to his father. Otherwise, how the tree would have wished to be praised!

Trees talk. And they correspond to your thoughts. Let me take another example. There used to stand a large plum tree in front of my parents' house. As is usual with old trees, it had a hollow. At the best time it usually bore more or less three eighteen-litre bamboo basketfuls of fruits. When the tree was declining, my mother requested my father to cut it because it was convenient when she turned the car but he was very reluctant. Pressed to reply, he answered, "Wait until next year. You needn't cut it immediately." My father disliked killing living organisms. He disliked cutting trees in the mountain, too. I hurried to the tree, and said, "You

may be cut down next year. Please bear more fruits to stop it.” As a young child, I felt sorry that it should be cut down. I liked plums and its white flowers. To my surprise, it bore many fruits the next year. I can vividly recollect his delightful face. An elder in an old village used to say that trees will bear fruits if you threaten to kill them. This may be the case with that plum tree at my parents’ house.

A *ume* tree certainly *flew* to Dazai-fu [a local administration agency established in the north of Kyushu, a south-western island of the Japan Islands in the seventh century], but my story goes as follows. A *ume* tree Michizane Sugawara loved must have been so graceful and noble that everybody wanted to acquire after he was exiled. *Ume* trees can endure easily for one or two months in the season when they fell their leaves. Hence, the *ume* tree loved by Michizane might have let itself pass from one hand to another on the journey, perhaps on board, to where he was exiled. The legend says that it flew over the night according to a legend, but it stole in to his residence, I suppose.

There also stands a pink drooping *ume* tree in our garden. It is so old that it forms an impressive blossom umbrella when it blooms full. We encountered the tree at a plant fair. It was brought into an auction several times but there were no bids. My husband wished for the *ume* tree. He begged to confirm my approval. Since I had been so inclined for some reason or other, I had it planted in our garden with a great pleasure. I was so concerned from where it came that I requested my husband to enquire wherefrom. As it turned out, the tree had formerly belonged to my husband’s older fellow gardener. The reason why the tree had left its former owner was that he had to commit it to the trader for its disposal when he needed space for a garage in the garden. The tree chose our garden. We planted it at the centre of our garden.

There was a camphor tree planted beyond the *ume* tree. This was one of the camphor trees grown out of seeds sized less than five millimetres sown in the garden. They agreed with the soil here and grew steadily. One after another has been sold occasionally but that one has remained there in our garden. Camphor trees are difficult to arrange in roots even if administered cuts and trims of the roots. Therefore they require much care for sale. My husband committed the remaining one to my disposal.

One day, perhaps, in the sixth year of the Heisei era [1994], as far as I remember, the predecessor of the present Chancellor, looking over the garden from

the window in her office, told me that the camphor tree over there in the campus had been carried to the campus from Kyushu for gift. At that time, camphor trees were grown by gardeners in Togane City including us. The competitive spirit prompted me to propose, "Chancellor, I will gift a camphor tree on the tenth or twelfth anniversary," with a ring formed with a hand, "since ours has grown of such a size." In reply, she said with a usual affectionate and protective smile, "We will buy it. You needn't gift it." It was my rashness, I repent.

Getting through some affairs, that remaining camphor tree at my disposal was eventually to come to an end, I was determined. I announced to my husband that it would be cut down the next day. However, the next morning, the *ume* tree in the central area of the garden bloomed fully, shone in the sunshine and turned its blossoms toward the camphor tree. I cannot forget the scene for my life. The *ume* tree implored me to stop cutting down the camphor tree. The camphor tree requested to come near to the Chancellor. To my awe the trees talked.

Through the courtesy of the University the camphor tree thereafter came to protect from the north wind the football pitch of the university. The members of the club had complained, I heard, that since there was no blockage toward the north, they had difficulty in controlling a ball when kicking it in that direction. Their complaint has some good reason because the residents here do not design their gates open toward the Kumano shrine. If the tree is of service to them, it is my pleasure.

A punchline follows. My husband, never believing in superstitions, yet trusting his spouse's inspiration, told me not to mention outside what you had heard, adding, "It is troublesome, Dame, if I am told, "Please let me take a leave." I nodded. Then, he declared, "This is a treasure in our garden."

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