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REVIEW

EDUCATION AND RESEARCHES NEEDED FOR WATER SUPPLY ENGINEERING IN THE 21 CENTURY

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Key Words : *water supply engineering, micro-energy science, hydro-energy science, monetary-energy science*

The author leaves some expectation illustratively for the future development of ware supply engineering. First, a perspective of water supply system in future including past decades, present topics and future perspective of the works was described. Second, education of water supply engineering was described including reform of university and water supply as a training and educational field. Next, basic requirements for new water supply engineering were shown illustrating the results of micro-energy sciences, hydro-energy sciences and monetary-energy sciences. The author points out that Sanitary Engineers must continue their studies to catch up new scientific developments to apply them to our field.

1. PREFACE

The author is also facing at his retirement from Kyoto University after a long struggle to establish Water Supply Engineering as a firm field to mainly educate students in the field of modern Environmental Engineering. They are requested to master from basic sciences to total management technologies including economic concepts, and from planning, designing, construction and maintenance with deep understanding of quality problems.

Here, he leaves some personal expectation illustratively for the future development of the water supply engineering, sacrificing scientific preciseness in the description.

2. A PERSONAL PERSPECTIVE OF WATER SUPPLY SYSTEM IN FUTURE

(1) Past decades

Water quality problems such as by carcinogenic substances and environmental hormones have been focused in these decades, following offensive flavor problems. Advanced treatment of the flavor substance, 2-methyl-isoborneol (2-MIB), was the major interest, leading to an employment of the activated carbon adsorption and ozonation in addition to the conventional treatment. In addition, the Membrane filtration technology is stimulating conventional sand filtration mainly in small scale treatment plants. However, the major impact was on the Hanshin-Awaji Earthquake damages on water supply system in 1995 in Japan. Concepts of risk management were introduced into construction and maintenance of water supply system.

(2) Present topics

In accordance with the national economical depression, structural reforms of public works have been major concern in these days, including water supply works. Government has changed the Water Supply Law, insisting on the policy change from uniform style of water supply work to diversification of it depending upon each regional requirements. It means the change from the nationally regulated work to the independent one under self-responsibility. In the new Law, Regionalization of the works, Entrustment of the works to external bodies and Open publication of the related information are also recommended.

(3) Future perspective of the works

The author had a chance being engaged in the governmental committee for the Basic Problems of the Water Supply Works (Kihon mondai kentoukai), which was a preliminary discussion for the change of the Law. Through the discussions, he felt sure the policy change from uniform style of works to regionally independent style of the works depending upon each regional requirements. That is from the nationally regulated one to locally free one under self responsibility including the privatization of the works in some special case.

3. EDUCATION OF WATER SUPPLY ENGINEERING

(1) Reform of university

As one of the structural reform of the public works above mentioned, national universities are also enforced to reform themselves to smaller or compact one. Some types of privatization of national university are under discussions mainly focusing on the engineering field which was expanded for the industrial recovery from the last war. Final goal of the reform is not clear at this moment, but classical or basic fields of engineering are expected to be cores of the reformed engineering. They believe that the applied science or engineering such as water supply engineering will be disappeared or should be grouped in a specific field.

(2) Water supply as a training field or as an educational field

The author insists on the importance of the water supply engineering as a training field or educational field because of the well balanced requirements of physics, chemistry and biology in addition to the covering process areas from planning to maintenance. Students can image up "what is the real role of engineering" as a base of engineering through studying water supply engineering. They may continue their major field after studying water supply engineering as a base of the engineering.

4. BASIC REQUIREMENTS FOR NEW WATER SUPPLY ENGINEERING-Some Example Studies-

Conventional Water Supply Engineering requires physics mainly hydro-power for the distribution of water, and some chemistry and biology for the quality measurements. However, in order to cope with the toxic substances, more precise chemistry and biology on molecular level must be involved. At the same time, for the management of the economically independent or self earning system, micro and macro economies must also be involved. In molecular level sciences, micro energy is a key factor as later shown. In other expression, for water supply engineering, multilevel of energy movements must be trained in well balanced form from human health problems to monetary management problems.

(1) Micro-energy sciences

As micro-energy sciences, molecular level of chemistry and biology are highly developed in these decades. Some example studies are shown as follows in related forms with water supply engineering.

a) A study of quantum chemistry

Theoretical chemistry has been greatly developed in these decades and it is already applied to the practical industries with fruitful results. In academic course, it is given in primal grades as one of basic requirements.

Theoretical background is in the mathematical description of electron movements. The next Sholedinger equation describes the harmonic vibration and circular movement of each electron;

$$-\frac{h^2}{8\pi^2 m}\cdot\frac{d^2\varphi(x)}{dx^2}+U\varphi(x)=E\varphi(x) \qquad (1)$$

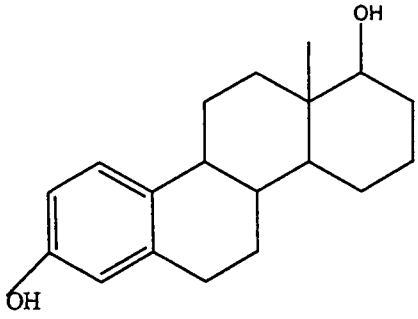
$$-\frac{h^2}{8\pi^2 m}\cdot\left(\frac{d^2}{dx^2}+U\right)\varphi(x)=E\varphi(x) \qquad (2)$$

$$H\varphi(x)=E\varphi(x) \qquad (3)$$

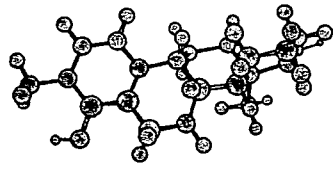
$$H=-\frac{h^2}{8\pi^2\mu}\left(\frac{(\partial\varphi)^2}{\partial x^2}+\frac{(\partial\psi)^2}{\partial y^2}+\frac{(\partial\psi)^2}{\partial z^2}\right) \qquad (4)$$

$$-\frac{e^2}{\sqrt{x^2+y^2+z^2}}$$

By solving the above differential equations (constant coefficient, 2nd order), structure of electron formation around nucleus which compose a molecule can be quantified. Number of electron is deter-

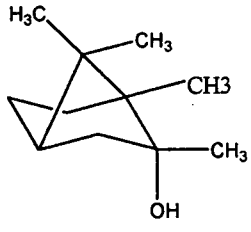


Input data of estradiol molecule

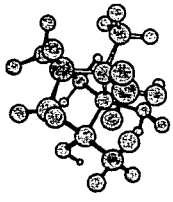


Output of 3-dimensional optimal structure

Fig. 2 Preliminary pre-treatment of estradiol using a Software.



Input data of MIB molecule



Output of 3-dimensional optimal structure

Fig. 1 Preliminary pre-treatment of 2-MIB using a Software.

mined by the electron charge of the nucleus and electrons in the form of a pair are distributed to the 1st, 2nd, 3rd, ...orbits around each nucleus. Maximum capacities of each orbit to accept electrons are 2, 6, 10, ...on the above each orbit. By finding minimum energy of a molecule, structure of a molecule or coordinates of all atoms which consist of the molecule can be calculated. For the calculation a powerful software is already prepared and easily purchased.

Chemical reactions are theoretically predicted through these calculations.

b) A case study; molecular structure of the offensive flavour 2-MIB

The molecule of the offensive flavor 2-methyl-isoborneol (2-MIB) is drawn as shown in **Fig. 1**, using the software Chem Draw. Transferring the given data to the software Chem 3 D, the 3-dimensional structure and the coordinates of each electron which consists the 2-MIB are given after the minimization calculation (MOPAC calculation prepared as a software). By giving the obtained coordinates data to the dvxa calculation developed by Adachi, HOMO (Highest Occupied Molecular Orbit) and LUMO (Lowest Unoccupied Molecular Orbit) are calculated by the software. From the Fukui theory (Nobel Prize winner's theory), electron transfer from HOMO to LUMO gives the approximate possibility of the following chemical reactions.

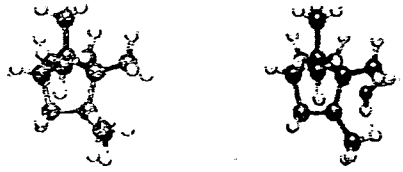
c) Possible chemical reactions

There are several methods to assume the following reactions theoretically in addition to the above, an example calculation of the reaction when pH is decreased in water with 2-MIB is shown in **Fig. 3**. (Here, the effects of pH is calculated when H^+ ion is located to the near location of 2-MIB are calculated, using the MOPAC software). The same type of calculations are conducted for the environmental female hormone Estradiol leading to the results shown in the **Fig. 2**.

More, generally, possible chemical reactions may be assumed from the following HOMO and LUMO calculated as shown in **Fig. 4**.

d) Electron Movements in the Field of Molecular Biology

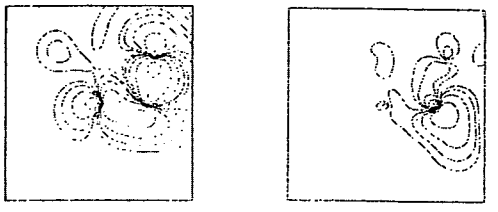
In addition to the above chemical reactions,



2-MIB with OH under a normal pH

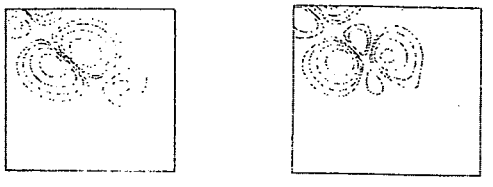
2-MIB releases OH under a pH value

Fig. 3 Calculated result of 2-MIB reaction from left to right by MOPAC.



Contour of 2-MIB HOMO

Contour of 2-MIB LUMO



Contour of estradiol HOMO

Contour of estradiol LUMO

Fig. 4 HOMO and LUMO of 2-MIB and estradiol.

biological reaction will also be theoretically estimated as an ordinal chemical reaction in very near future.

As summarized in **Fig. 5** illustratively, the knowledge of enzymes will be indispensable for the biological reactions in very near future.

Additional remarks of the **Fig. 5**; 1) Biological Body cannot utilize heat energy, 2) It gets energy through H uptake from reduced C under the enzyme existence.

In order to decompose 2-MIB biologically, *Ps. fluoescence* was isolated from the bottom debris of Lake Biwa. After an artificial growth of the bacteria, crude enzyme (all enzymes mixed) was obtained from the cell destruction by Ultra Sonic Dose. After the check of degradability of 2-MIB by the crude enzyme, it was separated as shown in **Fig. 6** using a Gel-filtration, and each separated fraction was measured which can decompose 2-MIB. Judging from the description in **Fig. 5**, ATP is a key as energy source of the reactions. However, the above experiment was conducted without any addition of ATP, because crude enzyme also contains ATP. If experiments after removing ATP from the crude enzyme will be conducted, energy requirements of related reactions will be quantified by adding ATP in the above experiment.

(2) Hydro-energy sciences

Hydro-power problems with kinetic and potential energies are quite conventional and popular in the water supply engineering. Therefore, descriptions are perfectly eliminated here. However, mainly for the both of the designs and the maintenance of equipments, hydro-power is the fundamental energy without any doubt for them in the 21 century.

(3) Monetary-energy sciences

Water supply works are financially independent as previously cited. All required expenses are basically provided by the water supply income only. There are two basic problems; one is the appropriate price determination and another is the preparation problems of the large funds for their facility renovations or is a finance problems. These problems are not real energy problems. However, the monetary balance sometimes depresses the entire works, and therefore "in and out balance" of money is simulated in the same concept with energy balance, employing the terminology "Monetary-energy" here.

a) A case study of IS-LM analysis for water supply works

For finance problems, IS-LM analysis is a proper method to simulate the money balance in the macro economic activities. Mathematical models as follow is often employed for the calculation.

Income Y; $Y=C+I+g$ (5)

governmental expenses g;

Expenses C; $C=100+0.6Y$ (6)

Investments I; $I=200-660r$ (7)

Supplied Money Amount M in money market;

$(M/P)=0.4-2000r$ (8)

Price rate P; $P[t]=(1+pi[t-1])P[t-1]$ (9)

Price adjustment pi;

$pi=0.25(y[t-1]-1250)/1250+pie$ (10)

Expected inflation;

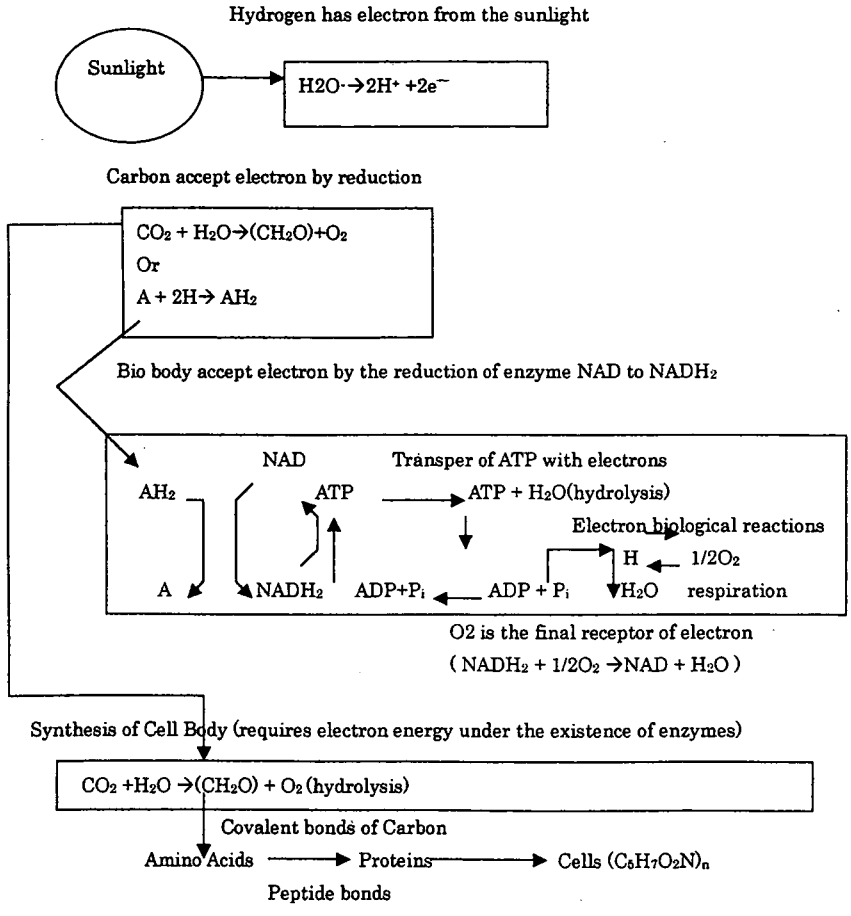


Fig. 5 Illustrative descriptions of the relations of electron movements with biological reactions.

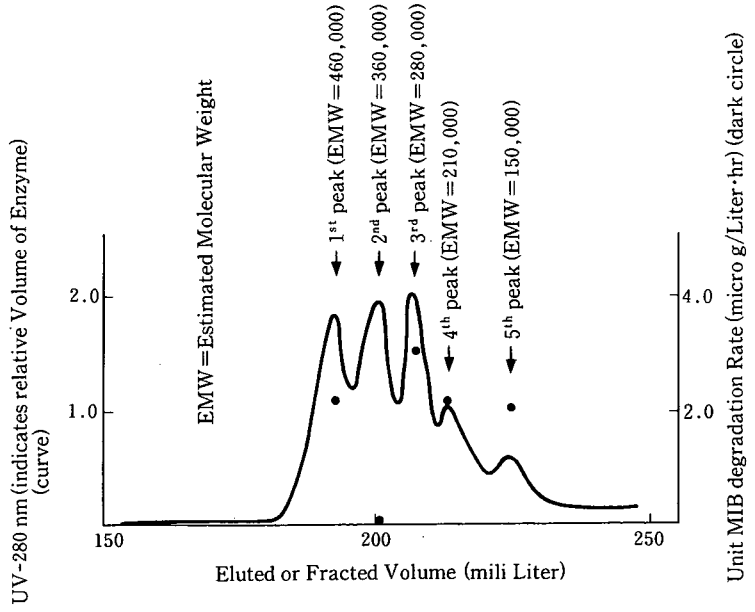


Fig. 6 An experimental result of enzyme's abilities to decompose 2-MIB without any addition of ATP and NAD.

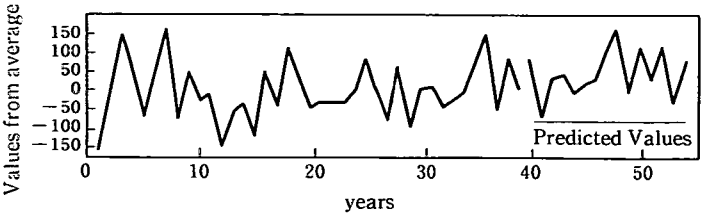


Fig. 8 A predicted result of simulated values in **Fig. 7** applying the ARIMA model of the time series method.

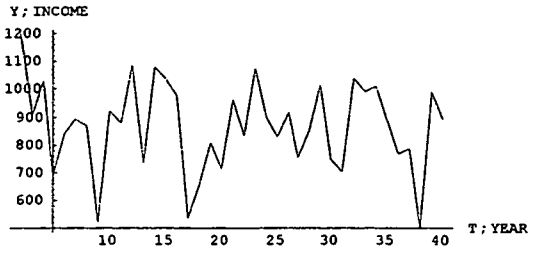


Fig. 7 A simulated result of the above economic model.

$$pie = 0.4pi[t-1] + 0.2pi[t-2] \qquad (11)$$

Supplied Money M for the market controls all economic activities; some are invested or saved, and the rest used for the required consumptions. In other expression, M can purchase money itself in the currency market and also can be used for material consumptions. In the following simulation, for the price adjustment, unexpected effect (s) is added, and the unexpected disturbance (z) is added for the total demand curve also. Unexpected effects are simulated with the normal random numbers in the calculation. An obtained result is shown illustratively in **Fig. 7**. The income Y or money for the consumption is simulated as an example. From this type of calculation, many types of financial problems will be solved in the future.

(4) Additional requirement for the future engineering

Prediction technology is focused here as an additional requirement for the future engineering. Prediction is the poorest technique in many fields of engineering. Therefore, the author dares to add the expectation of the establishment of more sophisticated prediction method depending upon the available data. Here, as one of such methodologies, Time Series Analysis is highly recommended for the future of water supply engineering as shown in **Fig. 8** in which a predicted result of the simulated values in **Fig. 7** is shown as an example utilization of a software ITSM.

For the future prediction for the engineering, mechanical backgrounds must be taken into account more. However, here most simple method is only shown calling attention on these subjects.

5. SUMMARY

Professor Tambo is now retiring from Hokkaido University after heavy duties as the President. In addition to his great scientific contribution to the field of Environmental Engineering, he has shown the future direction all Japanese Universities should go for the future as a President. The author feels great honor to be given this type of opportunity to express his cordial appreciation to the All Professor Tambo has shown for all of us.

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退官記念国際シンポジウム　発表文

Education and Researches Needed for Water Supply Engineering in the 21 Century

(21 世紀の水道工学に必要な教育と研究)

住友　恒

Summary の叙述的日本語訳

本文を終えるにあたり，筆者は次のようなことを力説したがっているようだ．

私共のプロとしての責務は「水の供給にともなう公衆衛生の確保にある」ことは言うまでもない．ただ，公衆衛生と個人にとっての衛生の間に何がしかの差があるか否か若干いぶかっているようである．本来，健

康とか幸せとは全く個人固有のものである．では，公衆衛生とはいったい何を指すのか？　関係するすべての個人の平均的健康を指すのか？　筆者は，独善的に「公衆衛生とは集団の中の最も弱者の健康問題にある」と力説したがっているようである．筆者が阪神・淡路大震災の折，厚生省の水道被害調査団長として現地に入った節，上のように，公衆衛生とは弱者あるいはもっとも悲惨な人の健康にあると痛感した．被害が99%回復しても，責務が完了したようには実感できなかった．5週間以上にわたっての水の無い生活を余儀なくされている人々がまだ1%も残っている．全員が復旧するまで責務は終わらないとの思いであった．この思いに悩まされると同時に，自分が衛生工学を学びそれを仕事としていることに誇りと満足感を味わうこととなった．私共の役割はすべての関係者が肉体的にも精神的にも健康を取り戻すまで継続するのだろうと．

こういった特異な経験から，表現を変えれば，人間が存在する限り，私共の責務は続く，かつ限りが無い，との思いである．

責務に究極のゴールは無いのか，せめて，努力を継続することによってのみ許されるようなものかもしれない．独り善がりかもしれないが，現実的には他分野での驚異的な科学進歩を人々に代わって勉学を続け，これを自分たちの専門分野に導入することによって，かろうじて赦免されるものかもしれないとの思いである．

翻って見るに，長きにわたりこの道のプロと自認してきた己の小ささと成果のなさを恥じ入るばかりである．せめて，本文を記載したことを機会として，退官とはいえ，さらなる勉学を継続し，少しでも人々のお役に立ち続けることをここに宣言したい思いである．

同時に，今日に至るまでこんな自分をやや大目に支え続けてくれたこれまでの学生諸氏に心からの謝意を表したい．関西水道事業研究会というすばらしい集団にも支えられてきた．感謝の思いを強めるばかりである．

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(本稿は以下に掲載されたものを再録したものである.)
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