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ANALYSIS AND FORMULATION OF COMBUSTIBLE COMPONENTS IN NON-HAZARDOUS SOLID WASTES

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ABSTRACT:

The non-hazardous solid wastes from industrial plants are similar to municipal solid wastes (MSW). An industrial plant is planning to reuse its own non-hazardous solid wastes as a supplemental source of fuel to its incinerator. The objectives of this research are: (a) to determine the energy values using both the modified Dulong Formula, and a traditional method; and (b) to determine the empirical chemical formula of the plant's own solid wastes using the values of ultimate analysis. This publication introduces the various solid wastes, (such as food, paper, cardboard, plastics, textiles, rubber, leather, garden trimming, wood, glass, tin cans, nonferrous metals, ferrous metals, dirt, and ashes), and their physical and chemical compositions (such as, percent by weight, dry weight, moisture content, inert residue, and energy content). Using the available typical MSW information, the energy values for the target industrial non-hazardous combustible solid wastes (excluding the wastes of glass, tin cans, nonferrous metals, ferrous metals, dirt, and ashes) were determined to be 5776 Btu/lb with the modified Dulong Formula and 6045 Btu/lb with the traditional method. The two calculated energy values are very close. The empirical chemical formula of the target solid waste was determined to be $C_{664} H_{1741} O_{745} N_{14.4} S$. This formula can be used by the plant's planners and managers in evaluating the feasibility of alternative uses of the target solid waste such as heat generation and materials recycling.

KEYWORDS

Industrial Non-hazardous Solid Waste, Municipal Solid Waste (MSW), Food Waste, Cardboard , Plastic, Rubber. Leather, Garden Trimming, Wood, Refuse Ash, Energy Value Analysis, Formulation, Model, Solid Waste Management, Planning

ACRONYM AND NOMENCLATURE

a	Weight of sample as delivered
APWA	American Public Works Association
b	Weight of sample after drying
C	Carbon, percent
H	Hydrogen, percent
MSW	Municipal solid waste
O	Oxygen, percent
S	Sulfur, percent
USEPA	US Environmental Protection Agency

TABLE OF CONTENTS

ANALYSIS AND FORMULATION OF COMBUSTIBLE COMPONENTS IN NON-HAZARDOUS SOLID WASTES

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1. INTRODUCTION

1.1 Solid Wastes

The term solid wastes is all inclusive and encompasses all sources, types of classifications, composition, and properties. Wastes that are discharged may be of significant value in another setting, but they are of little or no value to the possessor who wants to dispose of them. [1-7]. In the USA, a solid waste is officially defined by the US Environmental Protection Agency (USEPA) as the following: any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant or air pollution control facility discarded materials including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities Sect. 6903(27). The regulatory definition is found at 40CFR261.2(a)(1). Therefore, a solid waste is defined by the US regulation as any "discarded material" not expressly excluded by the US regulations. A material is considered "discarded" if it is "abandoned", "recycled", or "considered inherently waste-like". Accordingly, the discarded, abandoned, recycled, or waste-like materials generated from a laboratory facility, or an industrial plant are all considered to be solid wastes. [8]

1.2 Types of Solid Wastes

1.2.1. Food Wastes

Food wastes include the animal, fruit, or vegetable residues resulting from the handling, preparation, cooking, and eating of foods (also called garbage.). These wastes and will decompose rapidly, especially in warm weather. The nature of food wastes will significantly influence the design and operation of the solid waste collection system. Food wastes are generated at residences, cafeterias, restaurants, large institutional facilities such as hospitals and prisons, and facilities associated with the marketing of foods, including wholesale and retail stores and markets.

1.2.2. Rubbish

Rubbish includes combustible and noncombustible solid wastes of households, institutions, commercial activities, etc., excluding food wastes or highly putrescible materials. Combustible rubbish consists of materials such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture, and garden trimmings. Noncombustible rubbish consists of items such as glass, crockery, tin cans, aluminum cans, ferrous and other nonferrous metals, and dirt.

1.2.3. Ashes and Residues

They are the materials remaining from the burning of wood, coal, coke, and other combustible wastes in homes, stores, institutions, and industrial and municipal facilities for purposes of heating, cooking, and disposing of combustible wastes. Ashes and residues are normally composed of fine, powdery materials, cinders, clinkers, and small amounts of burned and partially burned materials. Glass, crockery, and various metals are also found in residues from municipal incinerators.

1.2.4. Demolition & Construction Wastes

They are generated by construction, remodeling, and repairing at individual residences, commercial buildings, and other structures. The quantities produced are difficult to estimate and variable in composition, but may include dirt, stones, concrete, bricks, plaster, lumber, shingles, and plumbing, heating, and electrical parts.

1.2.5. Special Wastes

They include street sweepings, roadside litter, litter from municipal litter containers, catch-basin debris, dead animal, and abandoned vehicles. Because it is impossible to predict where dead animals and abandoned automobiles will be found, these wastes are often identified as originating from nonspecific diffuse sources. This is in contrast to residential sources, which are also diffuse but specific in that the generation of wastes is a recurring event.

1.2.6. Treatment Plant Wastes

They are the solid and semisolid wastes from water, waste water and industrial waste treatment facilities. The specific characteristics of these materials vary, depending on the nature of the treatment process. At present, their collection is not the charge of most municipal agencies responsible for solid waste management. In many areas the disposal of animal manure has become a critical problem, especially for feedlots and dairies.

1.2.7. Hazardous Wastes

They are chemical, biological, flammable explosive, or radioactive wastes that pose a substantial danger, immediately or over time, to human, plant, or animal life. Typically, those wastes occur as liquids, but. they are often found in the form of gases, solids or sludge, in all cases, these wastes must be handled and disposed of with great care and caution according to the rules and regulations of the Federal and State government agencies.

1.3. Summary

The non-hazardous solid wastes from industrial plants are similar to municipal solid wastes (MSW). An industrial plant is planning to reuse its own non-hazardous solid wastes as a supplemental source of fuel to its incinerator. The objectives of this research are: (a) to determine the energy values using both the modified Dulong Formula, and a traditional method; and (b) to determine the empirical chemical formula of the plant's own solid wastes using the values of ultimate analysis. This publication introduces the various solid wastes, (such as food, paper, cardboard, plastics, textiles, rubber, leather, garden trimming, wood, glass, tin cans, nonferrous metals, ferrous metals, dirt, and ashes), and their physical and chemical compositions (such as, percent by weight, dry weight, moisture content, inert residue, and energy content). Using the available typical MSW information, the energy values for the target industrial non-hazardous combustible solid wastes (excluding the wastes of glass, tin cans, nonferrous metals, ferrous metals, dirt, and ashes) were determined to be 5776 Btu/lb with the modified Dulong Formula and 6045 Btu/lb with the traditional method. The two calculated energy values are very close. The empirical chemical formula of the target solid waste was determined to be $C_{664} H_{1741} O_{745} N_{14.4} S$. This formula can be used by the plant's planners and managers in evaluating the feasibility of alternative uses of the target solid waste such as heat generation and materials recycling.

2. CHEMICAL AND PHYSICAL COMPOSITION OF MUNICIPAL SOLID WASTES

2.1. Composition of Municipal Solid Wastes

Information on the composition of solid wastes is important in evaluating alternative equipment needs, systems, and management programs and plans. For example, if the solid wastes generated at some commercial facility consist of only paper products, the use of special processing equipment, such as shredders and balers, may be in order. Also separate collection may be considered if the city or collection agency is involved in a paper products recycling program. Evaluation of the feasibility of recycling and incineration depends on the chemical composition of the solid wastes.

The physical-and chemical composition of municipal solid wastes is discussed in this section. Discussion is limited to an analysis of municipal solid wastes because consideration of the composition of all types of wastes would add little useful information and is beyond the scope of this report, which deals principally with the management of municipal solid wastes (MSW).

2.2 Physical Composition

Information and data on the physical composition of solid wastes are important in the selection and operation of equipment and facilities, in assessing the feasibility of resource and energy recovery, and in the analysis and design of disposal facilities. The individual components that make up municipal solid wastes, and the moisture content and density of solid wastes, are described in the following discussion.

2.2.1. Individual Components

Components that typically make up most municipal solid wastes and their relative distribution are reported in Table 1.

TABLE 1 - Typical Physical Composition of Municipal Solids

	% by weight	
COMPONENTS	RANGE	TYPICAL
Food Wastes	6-26	15
Paper	25-45	40
Cardboard	3-15	4
Plastics	2-8	3
Textiles	0-4	2
Rubber	0-2	0.5
Leather	0-2	0.5
Gardening Trimmings	0-20	12
Wood	1-4	2
Glass	4-16	8
Tin Cans	2-8	6
Nonferrous Metals	0-1	1
Ferrous Metals	1-4	2
Dirt, Ashes, Brick, etc.	0-10	4

Although any number of components could be selected, those listed in Table 1 have been selected because they are readily identifiable and consistent with component categories reported in the literature and because they have proved adequate for characterization of solid wastes for most applications.

The percentages of municipal solid waste components vary with location, the season, economic conditions, and many other factors. For this reason, if the distribution of components is a critical factor in a particular management decision process, a special study should be undertaken, if possible, to assess the actual distribution. Even then it may still be impossible to obtain an accurate assessment unless a prohibitively large number of samples are analyzed.

2.2.2..Determination of Components in the Field

Because of the heterogeneous nature of solid wastes, determination of the composition is not an easy task. Strict statistical procedures are difficult to implement. For this reason, a more generalized field procedure has been developed for determining composition.

To ensure that the results obtained are sound statistically a large sample must be obtained. It has been found that measurements made on sample sizes of about 200 lbs. vary insignificantly from measurements made on samples of up to 1,700 lbs. taken from the same waste load. To obtain a sample for analysis, the load is first quartered. One part is then selected for additional quartering until a sample size of about 200 lbs. is obtained. It is important to maintain the integrity of each selected quarter, regardless of odor or physical decay, and to make sure that all the components are measured. Only in this way can some degree of a random and unbiased selection be maintained. Additional information has been published by The American Public Works Association (APWA).

2.2.3. Moisture Content

The moisture content (or water content) of solid -wastes usually is expressed as the weight of moisture per unit weight of wet or dry material. In the wet weight method of measurement, the moisture in a sample is expressed as a percentage of the wet weight of the material. In equation form:

$$\textbf{Moisture content (\%)} = [\,(a - b) / a\,] \times 100 \qquad (1)$$

where a = weight of sample as delivered; and b = weight of sample after drying [9]

Typical data on the moisture content for the solid waste components in Table 1 are given in Table 2. For most municipal solid wastes, the moisture content will vary from 15 to 40 pecent, depending on the composition of the wastes, the season of the year, and the humidity and weather conditions, and in particularly rain.

The use of the data in Table 2 to estimate the overall moisture content of solid wastes is illustrated in Table 3.

TABLE 2: Typical Data on Moisture Content of Municipal Solid Wastes (%)

COMPONENTS	RANGE	TYPICAL
Food Wastes	50-80	70
Paper	4-10	6
Cardboard	4-8	5
Plastics	1-4	2
Textiles	6-15	10
Rubber	1-4	2
Leather	8-12	10
Garden Trimmings	30-80	60
Wood	15-40	20
Glass	1-4	2
Tin Cans	2-4	3
Nonferrous Metal	2-4	2
Ferrous Metal	2-6	3
Dirt, Ashes, Brick	6-12	8

TABLE 3: Determination of Moisture Content for Typical Wastes Solid Wastes

COMPONENTS	TOTAL (%) BY WEIGHT	MOISTURE CONTENT (%)	DRY WEIGHT (%)
Food Wastes	15	70	4.5
Paper	40	6	37.6
Cardboard	4	5	3.8
Plastics	3	2	2.9
Textiles	2	10	1.8
Rubber	0.5	2	0.5
Leather	0.5	10	0.4
Garden Trimming	12	60	4.8
Wood	2	20	1.6
Glass	8	2	7.8
Tin Cans	6	3	5.8
Nonferrous Metals	1	2	1.0
Ferrous Metals	2	3	1.9
Dirt, Ashes, Brick	4	8	3.7
TOTAL	100		78.1

Note: Moisture content (%) = (100) / 100 = 21.9

2.2.4. Density

Density data are often needed to assess the total mass and volume of water that must be managed. Unfortunately, there is little uniformity in the way solid waste densities have been reported in the literature.. Sometimes no distinction has been made between un-compacted or compacted densities.

Because the densities of solid wastes vary markedly with geographic location, season of the year, and length of time in storage, great care should be used in selecting typical values. Municipal solid wastes as delivered in compaction vehicles have been found to vary from 300 to 700 lb/yd^3; a typical value is about 500 lb/yd^3 .

2.3 Chemical Composition:

2.3.1. Fuel Value Evaluation

Information on the chemical composition of solid wastes is important in evaluating processing and recovery options. For example, consider the incineration process. Typically, wastes can be thought of as a combination of semi-moist combustible and noncombustible materials. If solid wastes are to be used as fuel, the four most important properties to be known are: (a) Proximate Analysis of moisture (loss at 105°C for 1 hour), volatile Matter (additional loss on ignition at 950 °C), ash (residue after burning) and fixed carbon (remainder); (b) fusing point of ash; (c) ultimate percent content analysis of C (carbon), H (hydrogen), O (oxygen), N (nitrogen), S (sulfur), and ash; and (d) heating value.

Representative data on the ultimate analysis at typical municipal waste components in Table 2 are presented in Table 4. Improvement of the data in this table is discussed later in the report.

2.3.2. Energy Content

Typical data on the inert residue and calorific values for municipal wastes are given in Table 5. The calorific values are on an as-discarded basis. The Btu values in Table 5 can be converted to a dry basis by using the following equation:

$$\textbf{Btu/lb (dry)} = \textbf{Btu/lb (as discarded)} \, [\, 100 / (100 - \%\ \textbf{Moisture})\,] \qquad \textbf{(2)}$$

TABLE 4: Ultimate Analysis of the Combustible Components In Municipal Solid Wastes.

COMPONENT	CARBON	HYDROGEN	OXYGEN	NITROGEN	SULFUR	ASH
Food Wastes	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Cardboard	44.0	5.9	44.6	0.3	0.2	5.0
Plastic	60.0	7.2	22.8	–	–	10.0
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	–	2.0	–	10.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Garden Trimm-ing	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Dirt, Ashes, Brick	26.3	3.0	2.0	0.5	0.2	68.0

TABLE 5: Typical Data on Inert Residue and Energy Content of Municipal Solid Wastes.

	INERT RESIDUE, (%)		ENERGY, (Btu/lb)	
COMPONENT	RANGE	TYPICAL	RANGE	TYPICAL
Food Wastes	2-8	5	1,500-3,000	2,000
Paper	4-8	6	5,000-8,000	7,200
Cardboard	3-6	5	6,000-7,500	7,000
Plastics	6-20	10	12,000-16,000	14,000
Textiles	2-4	2.5	6,500-8,000	7,500
Rubber	8-20	10	9,000-12,000	10,000
Leather	8-20	10	6,500-8,500	7,500
Garden Trimming	2-6	4.5	1,000-8,000	2,800
Wood	0.6-2	1.5	7,500-8,500	8,000
Glass	96-99	98	50-100	60
Tin Cans	96-99	98	100-500	300
Nonferrous Metals	90-99	96	------	------
Ferrous Metals	94-99	98	100-500	300
Dirt, Ashes, Brick	60-80	70	1,000-5,000	3,000

The corresponding equation for the Btu per pound on an ash-free dry basis is:

Btu/lb (ash-free dry) = Btu (as discarded) [100 / (100 - % ash-moisture)] (3)

If Btu values are not available, the approximate Btu value can be determined by using the modified Dulong Equation:

Btu/lb = 145.4 C + 620 (H - l/8 O) + 41 S (4)

where C = Carbon, percent; H = Hydrogen, percent; O = Oxygen, percent; and S = Sulfur, percent. Energy values of typical municipal solid wastes with the given composition are computed in Table 6 and compared as follows.

3. RESULTS AND CONCLUSIONS

3.1 Determination of Energy Values

The regular non-hazardous solid wastes from an industrial plant is similar to municipal solid wastes (MSW). An industrial plant is planning to reuse its own non-hazardous solid waste as a supplemental fuel to its incinerator. The objectives of this research are to (a) determine the fuel value using both the modified Dulong Formula, and a traditional method; and (b) determine the empirical chemical formulae of the plant's own solid waste. Ultimate analysis values are used to determine the energy value and the representative empirical chemical formulae for the target solid wastes. These formulae can be used by the plant's planners and managers in evaluating the feasibility of alternative uses for the target solid waste such as heat generation and materials recycling. Columns 1 and 2 in Table 6 introduce the components and percent weight of the target industrial non-hazardous solid wastes which are similar to municipal solid wastes (MSW) in nature. So the surveyed MSW information from the literature will be useful for analysis of the target industrial solid wastes.

TABLE 6: Derivation of Energy Value for a Given Composition of Municipal Solid Waste

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
COMPONENT	WEIGHT (%)	DRY WT (%)	C	H	0	N	S	ASH
Food Waste	15	4.5	2.16	0.288	1.692	0.117	0.018	0.225
Paper	35	32.9	14.32	1.974	14.476	0.099	0.066	1.974
Cardboard	7	6.65	2.926	0.392	2.966	0.020	0.013	0.333
Plastic	5	4.9	2.94	0.353	1.117	-----	----	0.49
Textiles	3	2.7	1.485	0.178	0.842	0.124	0.004	0.068
Rubber	3	2.94	2.293	0.294		0.059	-----	0.294
Leather	2	1.8	1.08	0.144	0.209	0.18	0.007	0.18
Garden	20	8.0	3.824	0.48	3.04	0.272	0.024	0.36
Wood	10	8.0	3.96	0.48	3.416	0.016	0.008	0.12
		72.39	34.98	4.5	27.75	0.887	0.140	4.043

Columns 1 & 2 in Table 6 are given for the target solid waste to be investigated.

Column 3 = Column 2 - [(Moisture % content from Table 2) / 100] x (Column 2)

= Dry Weight % in Column 3

Example for the food waste: 15 - [70 /100] x 15 = 4.5

Columns 4 through 9 = Column 3 x [(Corresponding Value Table 4) /100]

= Ultimate Analysis

Example for determining the Energy value of food waste's carbon (C) in Column 4 of Table 6:

Table 6 Column 4 for Food Waste C

= Column 3 x [(Corresponding Value Table 4) /100]

= 4.5 % x [(48) / 100] = 2.16 in table 6 Column 4

A researcher can then use the same method to complete all data in Table 6. Since the dry weight of the target solid waste presented in Table 6 is 72.39 % (column 3 bottom), the moisture content of the solid waste is calculated to be 27.61 % (100 % - 72.39 % = 27.61 %).

Summation of energy values for a given composition of municipal solid waste (MSW) taken from the bottom of Table 6 needs modifications because H and O are part of H_2O or moisture. C, , N, S and Ash energy values are listed below, but H and O energy values are . calculated in below.

C = carbon , percent = 34.98 from Table 6

H = hydrogen, percent
= 4.58 + (contribution from moisture content)
= 4.58 + (fraction of H in H_2O) x (total % moisture)
= 4.58 + (2/18) x (27.61)
= 7.64

O = oxygen, percent
= 27.75 + (contribution from moisture content)
= 27.5 + (fraction of O in H_2O) x (total % moisture)
= 27.5 + (16/18) x (27.61)
= 52.29

N = nitrogen, percent = 0.88665 from Table 6

S = sulfur, percent = 0.14035 from Table 6

Ash = ash , percent = 4.043 from Table 6.

The approximate Btu value can then be determined by using the modified Dulong Equation (Equation 4) in which C = Carbon, percent; H = Hydrogen, percent; O = Oxygen, percent; and S = Sulfur, percent. :

$$Btu/lb = 145.4\ C + 620\ (H - l/8\ \ O) + 41\ S \qquad (4)$$

$$= 145.4\ (34.98) + 620\ [7.64 - (1/8)\ (52.290] + 41.8\ (0.14035)$$

$$= 5776\ Btu/lb$$

So 5776 Btu/lb is the approximate enery value using the modified Dulong formula (Equation 4).

Energy values of the target municipal solid wastes presented in Table 6 can also estimated by another method. Table 6 columns 1 and 2 show the target solid waste to be investigated. The last column of Table 5 introduces the typical energy value of each individual solid waste category. By combining the data of Table 6 Columns 1&2 and Table 5 last column, the researcher obtains Table 7 . The energy value calculated from Table 7 for the target solid waste (Table 6) is 6045 Btu/lb. It can be seen that the two energy values (5776 Btu/lb and 6045 Btu/lb) are very close.

TABLE 7: Calculation of Energy Value with Known Component Energy Values.

COMPONENT	% WEIGHT	ENERGY (Btu/lb)	AS DISCARDED (Btu/lb)
Food Waste	15	2,000	300
Paper	35	7,200	2520
Cardboard	7	7,000	490
Plastic	5	14,000	700
Textiles	3	7,500	225
Rubber	3	10,000	300
Leather	2	7,500	150
Garden	20	2,800	560
Wood	10	8,000	800
			6045

6045 is the calculated value using known energy values.

3.2 Determination of Empirical Chemical Formula

Table 8 presents the calculations for determination of an empirical chemical formula for the target solid waste

TABLE 8 . Calculations for determination of an empirical chemical formula for a target solid waste

ELEMENT	WEIGHT %	ATOMIC WEIGHT	NO. OF MOLES	INTEGER
C	34.98	12	2.915	664
H	7.64	1	7.64	1741
O	52.29	16	3.26812	745
N	0.88665	14	0.063332	14.4
S	0.14035	32	0.004385	1
ASH	4.043			

Using the calculations presented in Table 8, the empirical chemical formula of the target solid waste (See Table 6, Columns 1 and 2) is determined in below:

$$\mathbf{C_{664}\,H_{1741}\,O_{745}\,N_{14.4}\,S}$$

GLOSSARY [1-8]

Ashes and Residues: They are the materials remaining from the burning of wood, coal, coke, and other combustible wastes in homes, stores, institutions, and industrial and municipal facilities for purposes of heating, cooking, and disposing of combustible wastes. Ashes and residues are normally composed of fine, powdery materials, cinders, clinkers, and small amounts of burned and partially burned materials. Glass, crockery, and various metals are also found in residues from municipal incinerators.

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APPENDIX A

Editors of

"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"

1. Dr. Lawrence K. Wang (王 抗 曝)

Editor Lawrence K. Wang has served the society as a professor, inventor, chief engineer, chief editor and public servant (UN, USEPA, NY, Albany) for 50+ years, with experience in entire field of environmental science, technology, engineering, arts and mathematics (STEAM). He is a licensed NY-MA-NJ-PA-OH Professional Engineer, a certified NY-MA-RI Laboratory Director, a MA-NY Water Operator, and an OSHA Train-the-Trainer Instructor.

He has special passion, and expertise in developing various innovative technologies, educational programs, licensing courses, international projects, academic publications, and humanitarian organizations, all for his dream goal of promoting world peace. He is a retired Acting President/Professor of the Lenox Institute of Water Technology (LIWT), USA, a United Nations Industrial Development Organization (UNIDO) Senior Advisor in Vienna, Austria, and a former professor/visiting professor of Rensselaer Polytechnic Institute, Stevens Institute of Technology, University of Illinois, National Cheng Kung University, Zhejiang University, and Tongji University.

Dr. Wang is the author of 750+ papers and 60+ books, and is credited with 29 invention patents. He holds a BSCE degree from National Cheng Kung University, Taiwan, ROC, a MSCE degree from the University of Missouri, a MS degree from the University of Rhode

Island and a PhD degree from Rutgers University, USA. Currently he is the book series editor of CRC Press, Springer Nature Switzerland, Lenox Institute Press, World Scientific Singapore, and John Wiley.

Dr. Wang has been a Delegate of the People to People International Foundation, an American Academy of Environmental Engineers (AAEE) Diplomate, a member of WEF, AWWA, ASCE, AIChE, ASPE, CIE and OCEESA, and a recipient of WEF Kenneth Research Award (NY), Five-Star Innovative Engineering Award (first DAF drinking water plant in Americas), and Korean Pollution Control Association Award (Transfer of flotation technology to South Korea).

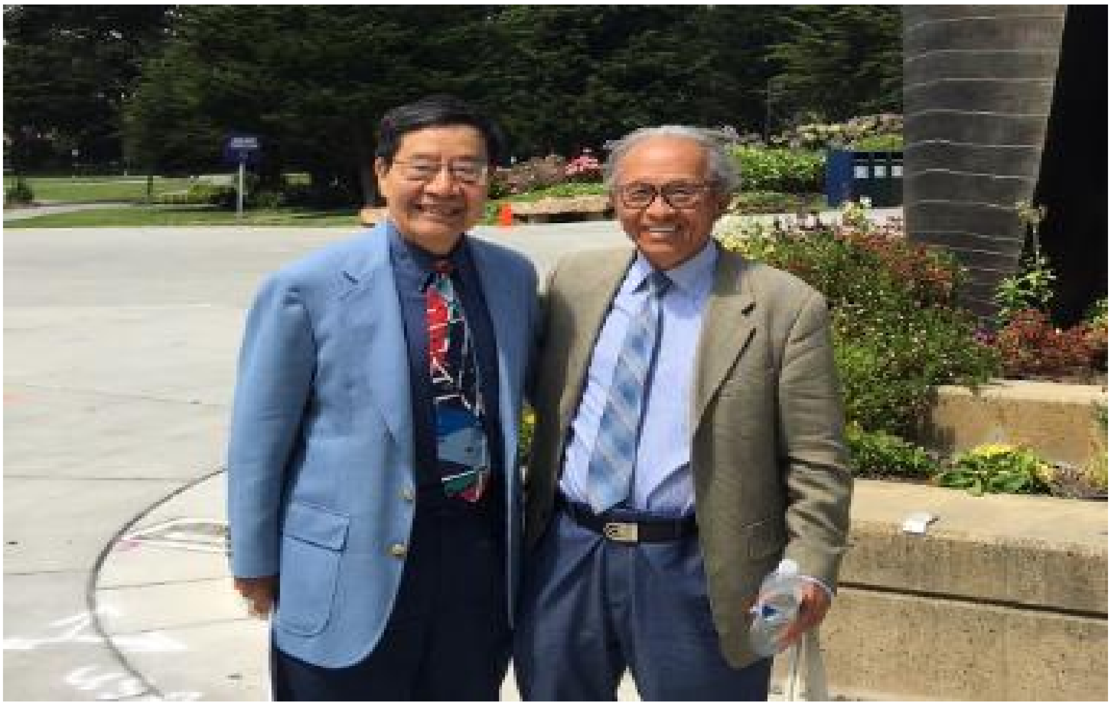
2. Dr. Hung-ping Tsao (曹 恆 平)

Editor Hung-ping Tsao has been a mathematician, a university professor, and an assistant actuary, serving private firms and universities in the United States and Taiwan for 30+ years. Dr. Tsao has been an Associate Member of the Society of Actuaries and a Member of the American Mathematical Society.

His research have been in the areas of college mathematics, actuarial mathematics, management mathematics, classic number theory and Sudoku puzzle solving. In particular, bikini and open top problems are presented to share some intuitive insights and some type of optimization problems can be solved more efficiently and categorically by using the idea of the boundary being the marginal change of a well-rounded region with respect to its inradius; theory of interest, life contingency functions and pension funding are presented in more simplified and generalized fashions; the new way of the simplex method using cross-multiplication substantially simplified the process of finding the solutions of optimization problems; the generalization of triangular arrays of numbers from the natural sequence based to arithmetically progressive sequences based opens up the dimension of explorations; the introduction of an innovative way to solve Sudoku puzzles makes everybody’s life so much easier and other STEAM project development.

Dr. Tsao is the author of 10+ books and over 40 academic publications. Among all of the above accomplishments, he is most proud of solving manually in the total of ten hours the hardest Sudoku posted online by Arto Inkala in early July of 2012 and introducing an easy way to play Sudoku in 2019.

He earned his high school diploma from the High School of National Taiwan Normal University, his BS and MS degrees from National Taiwan Normal University, Taipei, Taiwan, his second MS degree from the UWM in USA, and a PhD degree from the University of Illinois, USA.



Editors of the eBOOK Series of the *"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"*

Dr. Lawrence K. Wang (王抗曝) - - left

Dr. Hung-ping Tsao (曹恆平) -- right

APPENDIX B

THE E-BOOK SERIES OF

"EVOLUTIONARY PROGRESS IN SCIENCE,TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"

The acronym STEM stands for “science, technology, engineering and mathematics”. In accordance with the National Science Teachers Association (NSTA), “A common definition of STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy”.

The problem of this country has been pointed out by the US Department of Education that “All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers.” STEM learning and applications are very popular topics at present, and STEM related careers are in great demand.

According to the US Department of Education reports that the number of STEM jobs in the United States will grow by 14% from 2010 to 2020, which is much faster than the national average of 5-8 % across all job sectors. Computer programming and IT jobs top the list of the hardest to fill jobs.

Despite this, the most popular college majors are business, law, etc., not STEM related. For this reason, the US government has just extended a provision allowing foreign students that are earning degrees in STEM fields a seven month visa extension, now allowing them to stay for up to three years of “on the job training”. So, at present STEM is a legal term.

The acronym STEAM stands for “science, technology, engineering, arts and mathematics”. As one can see, STEAM (adds “arts”) is simply a variation of STEM. The word of “arts” means application, creation, ingenuity, and integration, for enhancing STEM inside, or exploring of STEM outside.

It may also mean that the word of “arts” connects all of the humanities through an idea that a person is looking for a solution to a very specific problem which comes out of the original inquiry process. STEAM is an academic term in the field of education. The University of San Diego and Concordia University offer a college degree with a STEAM focus.

Basically STEAM is a framework for teaching or R&D, which is customizable and functional, thence the “fun” in functional. As a typical example, if STEM represents a normal cell phone communication tower looking like a steel truss or concrete column, STEAM will be an artificial green tree with all devices hided, but still with all cell phone communication functions. This e-book series presents the recent evolutionary progress in STEAM with many innovative chapters contributed by academic and professional experts.