The Journal of Engineering and Technology Research (JETR) is published monthly (one volume per year) by Academic Journals.

Journal of Engineering and Technology Research (JETR) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Artificial Intelligence Applications and Innovations, Information Systems, Kinetic Processes in Materials, strength of building materials, engineering applications for world problems etc. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JETR are peer-reviewed.

Contact Us

Editorial Office: jetr@academicjournals.org
Help Desk: helpdesk@academicjournals.org
Website: http://www.academicjournals.org/journal/JETR
Submit manuscript online http://ms.academicjournals.me/
Editors
Dr. M.K. Oolun
*Acting Editor-in-chief, Executive Director*
ICT Authority
Level 12, Celicourt Building
6, Sir Celicourt Antelme Street
Port Louis, Mauritius

Oguz Bayraktar
Izmir Institute of Technology
Department of Chemical Engineering
Gülbahçe, Urla, TR35430 İzmir,
Turkey

Zdravko Spiric
Blankinijeva 21, 10000
Zagreb, Croatia

Soteris A. Kalogirou
P. O. Box 50329
Limassol 3603 Cyprus

Xingwen Liu
Institute of Electrical and Information Engineering,
Southwest University for Nationalities of China,
Chengdu, Sichuan, 610041,
Peoples Republic of China

Prof. Saeid Eslamian
Department Head of Water Engineering,
Isfahan University of Technology,
8415683111, Iran

Yuying Yan
Assoc. Professor & Reader in Thermo-fluids
Engineering School of the Built Environment
University of Nottingham,
University Park Nottingham NG7 2RD,
United Kingdom

Dr. K. G. Viswanadhan
N.S.S. College of Engineering,
Palakkad, Kerala Pin 678008

Ming-C Chyu
Department of Mechanical Engineering
Texas Tech University,
Lubbock, Texas 79409-1021

Cheong Kuan Yew
School of Materials and Mineral Resources
Engineering, Engineering Campus,
Sains University, Malaysia
Editorial Board

Dr. Kai-Long Hsiao
Department of Computer and Communication
Diwan University
Madou Town,
Tainan County 72153,
Taiwan

Prof. Bin Xu
College of Civil Engineering
Hunan University
Yuelu Mountain, Changsha,
Hunan, 410082
China

Dr. Emmanuel Osikhuemeh Aluyor
Ag. Head, Dept of Chemical Engineering,
University of Benin P.M.B. 1154
Benin City Nigeria

Dr. Sandeep Grover
YMCA Institute of Engineering
Faridabad, 2525
Sector 16, Faridabad,
India

Katya Marinova Simeonova
Institute of Mechanics,
Bulgarian Academy of Sciences
Acad. G. Bonchev, str.,
Bl. 4, 1113 Sofia,
Bulgaria

B. S. Shankar
# 876, 18th Main, 38th Cross,
4th ‘T’ Block Jayanagar,
Bangalore – 560 041,
India
Research Article

Cement production optimization modeling: A case study BUA plant
Joseph Sunday Oyepata and Otunuya Obodeh
Cement production optimization modeling: A case study BUA plant

Joseph Sunday Oyepata* and Otunuya Obodeh

Mechanical Engineering Department, Faculty of Engineering, Ambrose Alli University, Ekpoma, Edo State, Nigeria.

Received 24 March, 2015; Accepted 6 June, 2015

This paper deals with cement production optimization modeling using Particle Swarm Optimization (PSO) and the results was compared with Genetic Algorithm (GA) and Pattern Search (PS). This optimization modeling took into account mixtures of primary fuel (mineral coal, pet-coke and heavy oil) and its alternative fuel which is agricultural waste (rice husk, sugar waste and ground shell). The optimization simulation models predict the cost benefit to the manufacturer using alternative fuel, environmental impact to world and finally the quality of the cement produced to the end user. Production cost for one ton of cement using PSO ($23 = 4945), GA ($33 = 7095), PS (38.2 = 8170). The oxides in this research work met standard cement specification: Silica Modulus (M.S-2.9), Alumina Modulus (M.A- 1.3), Lime Saturation factor (LSF-93.3%). The results show that the cost of cement production can be reduced by 30 to 70% with the use of alternative fuel (Rice husk, Sugar cane waste, ground nut shell) and without greatly affecting the final product.

Key words: Fuel mixture, energy consumption, cement cost, cement quality.

INTRODUCTION

In cement production energy consumption takes the largest bulk of production cost. Due to this impact the cement manufacturers are always concerned about using alternative fuel mixture with low production cost without losing the quality of the final product and less environmental impact to the society. The process consists basically the replacement of the primary fuels by residues generated by other industries such as used tires, waste oils and other industrial wastes, agricultural waste, municipality waste, among others (Klepinger, 1993).

This research work presents the possibility of using the mixture of mineral coal, petroleum coke, heavy oil, agricultural waste (rice husk, ground nut and sugar cane waste), etc. as fuel feed stock. This mixture is intended for a rotary kiln, clinker production; mainly dry process with a pre-heater and calciner. The optimization procedure will take into account process restrictions such as specific heat consumption, cement quality and environmental impact.

Primary fuels used in cement industry are mineral coal, petroleum coal, gas oil and natural gas. These provide most of the energy needs of the World today. Coal and natural gas are used in their natural forms, but petroleum...
and other fossil fuels such as shale and bituminous sands require distillation and refinement to produce consumable fuels. These fuels exist in the following forms: Gaseous, liquid, and solid. The high cost of fossil fuels and most importantly, their damaging effect on the environment underscore the need to develop alternative fuel mixture for many industrial systems that rely on fossil fuels. Increased use of renewable and alternative fuels can extend life cycle of fossil fuel supplies and help resolve the present world global warming (Green House Gases) which is associated with the use of conventional fuels (Joseph and Obodeh, 2014).

Justification of the study

The cement manufacturing industry is under increasing pressure to reduce, cost of cement production and Green House Gas (GHG) emissions, such as carbon monoxide (CO), carbon dioxide (CO₂) and nitrogen oxide (NOx) (Conesa et al., 2008). It is estimated that 5% of global carbon dioxide emissions originate from cement production (Hendriks et al., 1998). These call for use of alternative fuel mixtures in cement plant which does not only afford considerable energy cost reduction, but also have significant ecological benefits of conserving non-renewable resources, the reduction of waste disposal requirements and reduction of Green House Gas emissions (Murray and Price, 2008). Use of low-grade alternative fuel mixtures in rotary kiln systems reduces GHG (Gabbard, 1990).

The finite nature of global fossil fuel resources, high prices and most importantly, their damaging effect on the environment underscore the need to develop alternative fuels for many industrial systems that rely on fossil fuels. Increased use of renewable and alternative fuels can extend fossil fuel supplies and help resolve air pollution problems associated with the use of conventional fuels (Kääntee et al., 2004).

Cement producers worldwide are striving to lower their production costs. One effective method of achieving this is the use of alternative fuels. Use of low-grade alternative fuels such as waste coal, tyres, sewage sludge, and biomass fuels (such as wood products, agricultural wastes, etc.) in precalciners is a viable option because combustion in a precalciner vessel takes place at a lower temperature (Roy, 2002; Smidth & Co., 2000). In precalciners where kiln exhaust gases pass through, the NOx emissions are much reduced due to re-burn reactions. There is an increased net global reduction in CO₂ emissions when waste is combusted in the cement kiln systems as opposed to dedicated incinerators, resulting in reduction in the CO₂ penalties. Since alternative fuels are often deemed cheaper than conventional fossil fuels, the possibility of a competitive edge is generated (Hewlett, 2004).

The use of alternative fuels in cement manufacture is also ecologically beneficial, for two reasons: The conservation of readily non-renewable resources, and the reduction of waste disposal requirements. The use of alternative fuels in European cement kilns saves fossil fuels equivalent to 2.5 million tonnes of coal per year (Cembureau, 1999).

Particle Swarm Optimization helps in the selection alternative fuel available among the spool of alternative fuel. The choice to be considered should at least have the following:

1. Kiln Stability
2. Best net calorific value
3. Economic and environmental importance

Particle swarm optimization helps in selecting raw materials simultaneously with fuels involving any combination and number of fossil fuels and waste derived fuels. The selection of the best possible solution is based on an economic objective function that accounts for the cost of raw materials, fossil fuels, alternative fuels and emissions.

Particle Swarm Optimization is initialized with a population of random solutions which is similar in all the evolutionary algorithms. Each individual solution flies in the problem space with a velocity which is adjusted depending on the experiences of the individual and the population. As mentioned earlier, PSO and its hybrids are gaining popularity in solving scheduling problems. A few of these works tackle the flow shop problem though application to hybrid flow-shops with multiprocessor tasks is relatively new (Yao et al., 2007).

This research work reviews in detail some of the main alternative fuels used in cement production and optimization. It focuses on types of alternative fuels used, the environmental and socio-economic benefits of using alternative fuels, challenges associated with switching from conventional or fossil to alternative fuels, combustion characteristics of the alternative fuels concerned, and their effect on cement production and quality (Winter et al., 1997). The aim of this research work is to provide empirical evaluation of alternative fuels. It offers an invaluable source of information for cement manufacturers that are interested in using alternative fuels. Researchers and students would also find this information valuable for their academic work and development.

The successful conduct of this research work would lead to reduction of primary fuel consumed and substituting the primary fuel with alternative fuel mixtures in BUA cement plant, since energy cost is the largest variable of the production cost. Through the particle swarm optimization model, it is possible to foresee (Carpio et al., 2005) the raw material composition when alternative fuel mixtures has been decided to be used as secondary fuels in cement plant.

It is also possible to calculate the substitution levels of the primary fuel by alternative fuel mixtures derived...
from agricultural wastes (rice husk, ground nut and sugar waste), being considered the acceptable and lowest pollutant emissions levels such as carbon dioxide, carbon monoxide and sulphur etc.

**Objective of the study**

The overall aim of the study is to develop readily and commercially available alternative fuel mixtures for achieving better stability of kiln operations, energy reduction and negative environmental impact minimization. The specific objectives are:

1. To carry out theoretical analysis and mathematical model using particle swarm optimization.
2. To determine the correlation between the cement standard results and empirical (experimental) results.
3. Comparing Particle Swarm Optimization model with other optimization model (Genetic Algorithms and Pattern Search).
4. To determine the effect of alternative fuel mixtures on; clinker quality, environmental impact, clinker production cost and cement production.

**MATERIALS AND METHODS**

The methodology of research is to use the Particle Swarm Optimization, Genetic Algorithm and Pattern Search simulation modeling. This will be generated from MATLAB software. Data used for this research was obtained from BUA cement plant laboratory and other foreign major cement group laboratory, such as Lafarge Group and Holcim Group, which are the largest cement manufacture in the world, while Flsmidth are the designer and manufacturer of cement equipment. The research results obtained (through optimization) will be compared with standard cement result.

Table 1 gives detail analysis of the raw material used to produce the raw meal for the kiln feed. Tables 2 and 3 are the detail analysis of primary fuels and alternative fuels (agricultural waste) used respectively for the production of cement.

**Data processing**

The method of analysis was the use of Particle Swarm Optimization, Genetic Algorithm and Pattern Search simulation modeling. Different sets of data were used at each stage. Thus the data were used at each simulation stage are based on the Raw material percentage (%) and Alternative Fuel percentage (%). The following training procedures were used:

1. A training set used in determining the Particle Swarm Optimization, Genetic Algorithm and Pattern Search simulation.
2. A validation set, used in estimating the Particle Swarm Optimization Genetic Algorithm and Pattern Search and decide when to start training.
3. Testing of the Particle swarm optimization Genetic Algorithm and Pattern Search tool with other optimization tools.
4. Inputting the result of the simulations and also checking that all the constraint X1, X2, X3 ...X10 are satisfied.

**Raw materials and fuel mixture model**

The material and fuel mixture optimization, was consider for the stable operation of the rotary kiln, the quality of the clinker produced, the minimum cost of the composition used and the electric power; all these variables are considered in the nonlinear model proposed through the following objective function, Equation (1) (Carpio, 2004, 2005).

\[ C = \sum Pic \times Xi + Pe \times A \times \exp(B \times S) \]  

(1)

The first term (linear) represents the raw materials and fuels (primary and alternative) costs used in the clinker production \((p_i)\) is the raw materials and fuels costs \(i = 1, 2, ..., 10\), that participate in the burning, with their respective percentages \(X_i\), \(X_2, ..., X_{10}\). The objective function \((C)\) of the model tried to obtain a minimum cost in the clinker production, considering the raw materials costs as well as the consumption of the energy required for grinding.

The second term (nonlinear) represents electricity cost \((p_e)\) and the energy consumption required in kWh/t for the grinding process of a certain specific surface \((S)\) is the specific surface area in \(\text{cm}^2/\text{g}\). \(A\) and \(B\) are constants that depend on the clinker composition.

Based on raw material, fuels chemical composition values and on the Equation (1), an objective function was set up, which represents costs minimization problem, considering the operational and environmental costs presented as it follows:

\[ \begin{align*}
M \cdot S &= \frac{(6.20X_1 + 63.62X_2 + 94.70X_3 + 3.6X_4 + 2.0X_5)}{(1.59X_1 + 26.84X_2 + 5.1X_3 + 93.95X_4 + 1.38X_5)} 
\end{align*} \]  

(3)

The constraints

\begin{align*}
52.18X_1 + 1.03X_2 + 1.01X_3 + 0.11X_4 + 0.18X_5 \geq 64 & (4) \\
52.18X_1 + 1.03X_2 + 1.01X_3 + 0.11X_4 + 0.18X_5 \leq 71.2 & (5) \\
6.20X_1 + 63.62X_2 + 94.70X_3 + 3.60X_4 + 2.0X_5 \geq 20.0 & (6) \\
6.20X_1 + 63.62X_2 + 94.70X_3 + 3.60X_4 + 2.0X_5 \leq 24.50 & (7) \\
1.12X_1 + 17.19X_2 + 3.67X_3 + 0.98X_4 + 1.07X_5 \geq 3.80 & (8) \\
1.12X_1 + 17.19X_2 + 3.67X_3 + 0.98X_4 + 1.07X_5 \leq 6.83 & (9) \\
0.47X_1 + 9.65X_2 + 1.43X_3 + 92.97X_4 + 0.31X_5 \geq 1.32 & (10) \\
0.47X_1 + 9.65X_2 + 1.43X_3 + 92.97X_4 + 0.31X_5 \leq 5.40 & (11) \\
0.80X_1 + 0.17X_2 + 0.08X_5 \leq 6.5 & (12) \\
28.2X_1 + 33.7X_2 + 43X_3 + 13.51X_4 + 15.47X_5 + 17.8X_6 \geq 3.60 & (13) \\
1.30X_1 + 4.00X_2 + 1.54X_3 + 0.04X_4 + 0.17X_5 + 0.02X_6 \leq 5.0 & (14) \\
0.05X_1 + 3X_2 + 0.78X_3 \geq 0.20 & (15)
\end{align*}
Table 1. Data of raw meal material preparation used.

| Material  | Limestone | Clay | Laterite | Iron |
|-----------|-----------|------|----------|------|
| Notation  | X₁       | X₂   | X₃       | X₄   |
| CaO       | 52.18    | 1.03 | 1.0      | 0.11 |
| SiO₂      | 6.20     | 63.62| 94.70    | 3.60 |
| Al₂O₃     | 1.12     | 17.19| 3.67     | 0.98 |
| Fe₂O₃     | 0.47     | 9.65 | 1.43     | 92.97|
| MgO       | 0.80     | -    | 0.17     | -    |
| SO₃       | 0.05     | 3.00 | 0.78     | -    |
| Na₂O      | 0.07     | 0.30 | 0.50     | -    |
| K₂O       | 0.20     | 3.00 | 1.28     | -    |

Table 2. Data of fuel composition employed as primary fuels.

| Component | Mineral coal % weight | Pet coke % weight | Heavy oil uses % weight |
|-----------|-----------------------|-------------------|-------------------------|
| Notation  | X₅                    | X₆                | X₇                      |
| C         | 70.60                 | 89.50             | 84                      |
| H         | 4.30                  | 3.08              | 12                      |
| N         | 1.20                  | 1.71              | Trace                   |
| O         | 11.8                  | 1.11              | 1                       |
| S         | 1.30                  | 4.00              | 3.00                    |
| Cl        | 0.07                  |                   |                         |
| P₂O (In ash) | 0.02                |                   |                         |
| Na₂O (In ash) | 0.05                  |                   |                         |
| K₂O (In ash) | 0.12                  |                   |                         |
| CaO (In ash) | 0.18                  |                   |                         |
| Fe₂O (In ash) | 0.31                  |                   |                         |
| Al₂O (In ash) | 1.07                  |                   |                         |
| SiO₂ (In ash) | 2.00                  |                   |                         |
| MgO (In ash) | 0.08                  |                   |                         |
| NiO (In ash) | -                     | 0.04              |                         |
| LHV (kJ/kg) | 28,800                | 33,700            | 43,000                  |

Table 3. Data of fuel composition employed as alternative fuels.

| Component | Rice husk % weight | Sugar cane % weight | Ground nut shell % weight |
|-----------|--------------------|---------------------|---------------------------|
| Notation  | X₈                 | X₉                  | X₁₀                       |
| C         | 37.48              | 41.16               | 45.9                      |
| H         | 4.41               | 5.08                | 5.34                      |
| O         | 33.27              | 37.42               | 36                        |
| N         | 0.17               | 0.14                | 1.09                      |
| S         | 0.04               | 0.02                | 0.01                      |
| Cl        | 0.09               | 0.01                |                           |
| LHV(kJ/kg) | 13,517              | 15,479              | 17.8                      |

0.05X₁ + 3.0X₂ + 0.78X₃ ≤ 2.07 \hspace{1cm} (16) \hspace{1cm} 0.07X₁ + 0.3X₂ + 0.5X₃ ≤ 0.33 \hspace{1cm} (18)
0.07X₁ + 0.3X₂ + 0.5X₃ ≥ 0.03 \hspace{1cm} (17) \hspace{1cm} 0.2X₁ + 3X₂ + 1.28X₃ ≥ 0.31 \hspace{1cm} (19)
Table 4. Summary of result.

| Objective function cost (C) | Oxides composition in clinker (%) | Modulus | Specific heat consumption |
|-----------------------------|----------------------------------|---------|--------------------------|
| $22.9646 \text{ US}\$ = 4945(naira) |                                |         | $= 3.6 \text{GJ/ton of clinker}$ |
| $X_1 = 1.2495$            | $X_2 = 0.1687$               | $X_3 = 0.0436$  | $X_4 = 0.0120$  |
| $X_5 = 7.4977e-06$ | $X_6 = 4.197e-08$ | $X_7 = 3.898e-7$ | $M.S = ((\text{SiO}_2/\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3)) = 2.9$ |
| $X_8 = 5.4881e-07$ | $X_9 = 0.0236$ | $X_{10} = 5.64749e-06$ | $M.A = (\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3) = 1.3$ |

The solution to this optimization problem finds the best clinker composition, satisfying all objective function, constraint and restriction in the equation, with all parameters within standard cement allowable range. The solution for the optimization model is a function of the specific heat consumption and of the operational and environmental restrictions.

### Results and Discussion

Optimization simulation runs results at 20 using Matlab software (Matlab 7.13). The grinding process of the cement a specific surface area $S = 0.38 \text{ cm}^2/\text{g}$ were used. The laptop used was Intel(R) Core™ i5-2540M CPU at 2.60 Hz RAM 4.00 GB, system type 32-bit operating system. In this case, the required chemical composition is sought for a cement type produced in a rotary kiln, dry process with heat specific consumption of 3600 clinker kJ/kg. The parameters of PSO, GE and PS used a population of 100 particles; $C_1 = C_2 = 2.0$; initial weighted (theta) of 0.9 with linear decline up to 0.3; search space of the variables to be optimized in the interval $0 < X_i < 3$, where $n=1,.., 10$. The cost used for this simulation are local market cost based in Nigeria where one (1) dollar $ = 215 \text{ naira}$.

The PSO has the lowest standard deviation and best average cost of producing one (1) ton of cement. All the constraints in the Equations (1) to (20) are all satisfied for PSO, GA and PS. To produce one (1) ton of cement using PSO, GA, PS model, it is expected that an average cost of $23 = 4945 \text{ naira}$, GA $= 33.0 = 7095 \text{ naira}$ and PS $ = 38.2 = 8170 \text{ naira}$ respectively are needed to produce one ton of cement. PS has the highest cost of producing one ton of cement Table 4.

The results in the above solution correspond to a final clinker composition, satisfying all objective function, constraint and restriction in the equation, with all parameters within standard cement allowable range. The solution for the optimization model is a function of the specific heat consumption and of the operational and environmental restrictions.

### Conclusion

In cement production equipment optimization, the operating rate is different from design rate of the equipment. The design rate gives room for increasing or decreasing the feeding phase for the raw meal and the fuel usage in a rotary kiln allows some freedom for change in the composition of raw meal (raw mix and corrective materials) and fuel consumption. The aim is to minimize cost of production without losing the quality of the final production, prolong the life of the equipment, while satisfying the environmental and operational restriction. The alternative fuel used is an agricultural waste (sugar cane waste, ground nut shell and rice husks) and primary fuel are mineral coal, pet-coke and heavy oil. These Agricultural wastes present a great potential use in the production of cement via rotary kilns. A model is presented in this paper work in which the composition of the raw meal and the fuels mixtures enters as variables of a non-linear programing problem. The solution to this optimization problem finds composition values for the variable which will result is a cement production with low free lime (CaO) 0.5-1.5, less
environmental pollutants and good quality cement production.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Carpio RC, Silva RJ, Jorge AB (2004). Heavy metals influence in the mixture optimization of industrial waste fuels in cement industry, XXV Iberian Latin-American Congress on Computational Methods in Engineering, Recife, PE, Brazil.

Carpio RC, Coelho LS, Silva RJ, Jorge AB (2005). Case Study in Cement Kilns Alternative Secondary Fuels Mixing Using Sequential Quadratic Programming, Genetic Algorithms, and Differential Evolution, Proceedings of 6th World Congress on Structural and Multidisciplinary Optimization, Rio de Janeiro, RJ, Brazil.

Conesa JA, Font R, Fullana A (2008). Kinetic Model for the combustion of tyre wastes. Chemosphere 59:85-90.

CEMBUREAU (1999). Environmental Benefits of Using Alternative Fuels in Cement Production, 19:25-39.

Smidth FL and Co. (2000). Dry process kiln systems, technical brochure.

Gabbard WD, Gossman D (1990). Hazardous waste fuels and the cement kilns – The Incineration Alternative. ASTM Standardization News, September 1990. http://gcisolutions.com/HWF&CKS.htm, Accessed August 2014.

Gulyurtlu I, Boavida D, Abelha P, Lopes MH, Cabrita I (2005). Co-combustion of coal and meat and bone meal. Fuel 84:2137-2148.

Hendriks CA, Worrell E, De Jager D, Blok K, Riemer P (1998). Emission reduction of Greenhouse Gases from the cement industry presented at the 4th International conference on Greenhouse Gas Control Technologies, 30 August – 2 September 1998, Interlaken, Switzerland.

Hewlett PC (2004). LEA’s Chemistry of Cement and Concrete (4th Ed). Elsevier Butterworth-Heinemann. 3:45-57.

Joseph SO, Obedeh O (2014). Optimizing Alternative Fuel mixtures in Cement Plant (BUA Cement Plant), Using Particle Swarm Optimization Method.

Kääntee U, Zevenhoven R, Backman R, Hupa M (2004). Cement manufacturing using alternative fuels and the advantages of process modeling. Fuel Process. Technol. 85:293-301.

Kleppinger EW (1993). Cement Clinker: an environmental sink for residues from hazardous waste treatment in cement kilns. Waste Manag. 13:553-572.

Murray A, Price L (2008). Use of Alternative Fuels in Cement Manufacture: Analysis of Fuel Characteristics and Feasibility for Use in the Chinese Cement Sector, Ernest Orlando Lawrence Berkeley National Laboratory, 10 March 2011.

Roy GR (2002). Petcoke combustion characteristics. World Cement 139:2-3.

Winter F, Prah ME, Hofbauer H (1997). Temperature in a fuel particle burning in a fluidized bed: The effects of drying, devolatilization and char combustion.

Yao K, Li F, Liu X (2007). An improved multi-particle swarm co-evolution algorithm. 3rd International Conference on Natural Computation. 3:51-55.
Journal of Engineering and Technology Research

Related Journals Published by Academic Journals

- Journal of Chemical Engineering and Material Science
- International Journal of Water Resources and Environmental Engineering
- Journal of Civil Engineering and Construction Technology
- International Journal of Computer Engineering Research
- Journal of Electrical and Electronics Engineering Research
- Journal of Engineering and Computer Innovations
- Journal of Mechanical Engineering Research
- Journal of Petroleum and Gas Engineering