Rationalization of water supply management in industry within the framework of the concept of sustainable development

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Abstract. Rational water use is enshrined by the UN for sustainable development. The lack of specification of methods for evaluating water supply in different sectors of industry determines the relevance of the study. The purpose of the study is to develop the water supply management system in industry within the framework of sustainable development. There are the following tasks: to systematize the directions of rationalization of water use in Russia; to identify regional specifics of water resources use in Russia. The object of research is water resources used in Russian industry. The subject of the study is the relations arising in the process of water use. Research methods: comparison, correlation, regression, cluster analysis. The rationalization of water use is highlighted: ICT development, ecologization of production, raising incomes, reducing unemployment; innovation and reviewing the quality of the patents. With regard to water use in the regions, it is necessary to tighten monitoring of polluting emissions into the atmosphere and increase the level of recycled water use. The results of the study are recommended for implementation in Russian industrial enterprises.

Keywords: sustainable development, water resources, rationalization, industry, economic and mathematical model, cluster analysis.

1 Introduction

One of the global sustainable development goals identified by the UN in 2015 is the rationalization of water resources use, as outlined in Goal 6 "Ensure access to water and sanitation for all" and Goal 12 "Ensure sustainable consumption and production patterns". The goal is also to use water efficiently in all sectors of the economy.

The problem of measuring and evaluating sustainable development has been at the heart of scientific research over the past two decades. At the initial stage of forming the methodology for assessing sustainable development, the papers contained an assessment of the system of indexes and indicators, which is reflected in the study by G. Mitchell [1]. Today, scientists, namely, A. N. Dyrdonova, T. S. Lin'kova, and S. Khusnutdinova assess the current state of development sustainability at the macro, meso and micro levels [2, 3], V. P. Meshal'kin, V. I. Bobkov, and T. V. Malysheva investigate resource-saving mechanisms [4–6]. Also in the modern scientific literature are presented the results of studies that reveal the author's methods of assessing sustainable development. The team of scientists S. C. L. Koh, J. Morris, S. M. Ebrahimi and R. Obayi proposed the IRE index, which is fundamentally a synthesis of the human development index and green growth indicators developed by the OECD. The index is focused on identifying the discrepancy between social well-being and resource efficiency, as well as ensuring green supply chains [7]. The works of Russian scientists A. A. Lubnina, M. V. Smolyagina and A. N. Melnik reflect a comprehensive approach to the formation of an aggregate indicator of sustainable development and determining the reliability of production\textsuperscript{[8, 9]}, in the works of S. N. Bobylev – a set of indicators necessary for monitoring the achievement of sustainable development goals in Russia [10], and others.

The UN formalization of the 17 sustainable development goals has served as a driver for the development of integrated approaches to assessing and ensuring sustainable development and use of
water resources. A number of papers (C. Cook et al., A. Moumen et al., A. K. Gain et al.) is devoted to the study of the concept of water safety [11–13]. Author teams led by A. Wutich and Y. Aihara presented a methodology for assessing water security through the lens of emotional and psychological stress, including a systematic approach to studying the problem of water scarcity and lack of water security, which is due to inadequate water supply, lack of access to water distribution systems, and dependence on seasonal water sources and gender, since the female sex is most susceptible to stress in the process of gaining access to water distribution systems [14, 15]. The economic nature of water safety assessment is also reflected in a number of studies. Among the previously proposed methods, the Global water security index (GWSI), developed by A. K. Gain et al. [13]; Water insecurity index (WII) used in India, reflected in the works of K. J. Aggarwal et al. [16]; The national water security index (NWSI), presented in the report of the Asian Development Bank [17]; Objective index of household water security (OI), authored by S. Shrestha et al. [18].

A set of research papers by authors J. Morris and D. D. Zhang, including the Water Sustainable Development Index (WSDI), is also devoted to assessing water use from the point of view of socio-economic development [19, 20]. G. Yang proposed a dual method of integrated assessment of water, economic, environmental and social subsystems as a fundamental approach to ensuring sustainable development of water resources, which combines the entropy method and the theory of finding the best projection [21].

In general, it should be emphasized that studies that reflect the relationship of sustainable development indicators with the UN sustainable development goals are already being conducted, but are of a general nature, without taking into account the specifics of the type of resources. An analytical review of a set of scientific papers devoted to the development of a methodology for assessing water resources management in order to ensure sustainable development allows us to state that there is currently no specification of methods for assessing the use of water resources by different sectors of industry.

2 Materials and methods

2.1 Correlation and regression analysis of the dependence of industrial water use indicators on the parameters of sustainable development

The nature of the dependencies between the studied data sets is estimated by identifying the correlation coefficients \( r \) and constructing regression equations that represent the equation of the dependence of \( y \) (dependent variable) on \( x_i \) (independent variables). The correlation coefficient is considered "material" if its value is from 0.7 to 0.99 (in accordance with the Chaddock scale). The study also constructed multiple linear regression equations for two and three variables, the general form of which is represented by the Eq. (1):

\[
y = a_0 + a_i x_i, \tag{1}
\]

where \( a_0 \) is a constant, a free term of the regression equation, the value of \( y \) if \( x_i = 0 \);

\( a_i \) is the regression coefficient, the angular coefficient, determines the slope of the regression line relative to the coordinate axes.

Dependency detection tool - "Excel / Data Analysis / Correlation" and "Excel / Data Analysis / Regression". The quality of the regression equation is evaluated primarily by three criteria. The coefficient of determination \( R^2 \), which exceeds 0.9, reflects the high accuracy of the variables included in the regression equation. \( F \)-ratio test allows us to evaluate the adequacy, reliability and statistical significance of the resulting equation. To do this, a comparison of the received and table values is performed. The latter is determined using the FINV function, where the probability associated with the \( F \)-integral distribution is assumed to be 0.05; degrees of freedom \( k_1 \) correspond to the number of
independent variables included in the regression equation; degrees of freedom $k_2$ correspond to the number of observations reduced by the number of independent variables and by 1. If the calculated value of $F$ exceeds the tabulated value, the equation is considered significant. The t-student tabulated value allows evaluating the significance of regression coefficients. To calculate the table value $t$, use the TINV function with a probability of 0.05 and a degree of freedom $k_2$. The coefficients for which the calculated t-value exceeds the table value are considered significant.

The study is based on an assessment of industrial water use in the context of sustainable economic development. In this regard, the set of independent variables reflects the achievement of the sustainable development (SD) goals set by the UN members in 2015 (Table 1).

### Table 1. The given data for building economic and mathematical models and their compliance with sustainable development goals.

| Dependent variable | The goal of SD | Indicators                                                                 |
|--------------------|---------------|---------------------------------------------------------------------------|
| Goal 12.          |                | – consumption of water resources in the field of mining, 1 cubic meters / 1000 rubles ($Y_1$); |
|                    |                | – consumption of water resources in the sphere of processing industries, 1 cubic meters / 1000 rubles ($Y_2$); |
|                    |                | – consumption of water resources in the field of production and distribution of electricity, gas and water, 1 cubic meters / 1000 rubles ($Y_3$); |
| Goal 3.           |                | – morbidity of the population by main classes of diseases, per 1000 people ($x_3$); |
| Goal 8.           |                | – unemployment rate, % ($x_8$); |
| Goal 9.           |                | – volume of innovative goods, works, and services, billion rubles ($x_9.1$); |
|                    |                | – use of protected results of intellectual activity in Russia, thousand units ($x_9.2$); |
|                    |                | – expenditures on information and communication technologies (organizations in the field of mining), billion rubles ($x_9.3$); |
| Goal 10.          |                | – average per capita income of the population (per month), thousand rubles ($x_{10}$); |
| Goal 12.          |                | – captured and neutralized pollutants, million tons ($x_{12}$); |

### 2.2 Clustering of Russian regions depending on the nature of water use and environmental load

The array of observations was formed from 79 subjects of the Russian Federation (with the exception of the Republic of Kalmykia, Sevastopol, and the Republic of Ingushetia due to the lack of statistical data on the studied parameters).

The following indicators for 2018 were selected as clustering parameters:

- $x_1$ is million cubic meters, million cubic meters;
- $x_2$ is recycled and consistent use of water, million cubic meters;
- $x_3$ is emission of pollutants into atmosphere, thousand tons;
- $x_4$ is atmospheric pollutants captured and neutralized, thousand tons.

Clustering is performed using the $k$-means method, which allows aggregating a set of subjects of the Russian Federation into a given number of clusters.

The quality of the selected clusters is evaluated in the framework of a variance analysis based on the values of $F$-statistics and significance levels $p$ with a significance level below 0.05 are recognized as significant.
3 Results

At the first stage, trends in the use of water resources for economic purposes within the framework of sustainable development, namely, in the segment of the ecological and economic system, are evaluated.

As a result of the study of correlations between water use indicators and economic indicators, a significant relationship was found between the level of discharge of contaminated wastewater and such socio-economic indicators as:

- number of students enrolled in bachelor's, specialty, and master's programs \( (r = 0.65) \);
- population, thousand people \( (r = 0.81) \);
- volume of shipped goods of own production, performed works and services by own forces for processing industries, million rubles \( (r = 0.77) \);
- the volume of shipped goods of own production, performed works and services on their own to provide electricity, gas and steam, million rubles \( (r = 0.72) \).

At the same time, the impact of the extractive industry on the level of discharge of contaminated wastewater is very weak \( (r = 0.15) \). Figure 1 shows the dynamics of the specific consumption of water resources (per 1000 rubles) in different sectors of industry in Russia, which is the ratio of the volume of water extracted from water bodies to the volume of products shipped.

![Figure 1. Change in water resources consumption by type of economic activity.](image)

There is a decrease in the consumption of extracted water resources in the energy sector (by 44.7 % in 2009-2016) and in the manufacturing industry (by 67.1 %), which generally confirms the high correlation of the shipments volume of these industries with water pollution. The level of water consumption for mining, on the contrary, increases (by 22.2 %). One of the factors of this trend is the change in the level of water recycling. The coefficient of recycled water use is calculated as the ratio of the volume of recycled water resources to the volume of water intake from natural water bodies (Figure 2). The growth of water resources savings due to the recycling and sequential water supply of industrial facilities is typical for the energy and manufacturing industries.
At the second stage, in order to identify areas of rational water use by industrial facilities in Russia, the dependence of water resources consumption levels on indicators that characterize the achievement of sustainable development goals is given (Table 1).

As a result, linear regression equations are constructed that determine the direction of rationalization of water resources management in Russian industry (Table 2).

Table 2. Economic and mathematical models of dependence of water resources consumption on sustainable development parameters.

| Models | Model quality assessment |
|--------|------------------------|
| $Y_1 = 3.04 - 0.0028x_3 - 0.002*x_9 - 0.0099*x_{12}$ | $R$-square = 0.971; $F_{calc} > F_{tabl} (44.58 > 6.944)$; |
| $Y_2 = 0.15 + 0.039*x_8 - 0.0082*x_{10}$ | $R$-square = 0.985; $F_{calc} > F_{tabl} (168.36 > 5.786)$; |
| $Y_3 = 13.54 - 0.0015*x_{9,1} + 0.39*x_{9,2} - 0.41*x_{10}$ | $R$-square = 0.976; $F_{calc} > F_{tabl} (53.351 > 6.944)$; |

Estimation of statistical reliability of the constructed models based on $R$-square, as well as the $F$-ratio test and the t-test (in all cases $t_{calc}$ exceeds $t_{tabl}$), confirms the adequacy of the constructed equations and the significance of the obtained regression coefficients. On the basis of these linear regression equations, a set of directions for rationalizing water resources management in industry within the framework of the concept of sustainable development is proposed (Figure 3).

Figure 2. Coefficient of circulating water use by type of economic activity.

![Figure 2](image-url)
Figure 3. Directions of rationalization of water resources management by industry sectors within the framework of the concept of sustainable development.

At the same time, it should be noted that the obtained model of dependence of water resources consumption on mineral extraction processes also includes an indicator of morbidity. When predicting the water level, it is necessary to take into account that an increase in the incidence rate for 1 case per 1000 people, ceteris paribus, will lead to a decrease in water consumption by 0.0028 cubic meters / 1000 rubles.

Also of interest is the inverse dependence of the Y1 on the use of protected intellectual property results. We believe that the revealed nature of the parameter relationship is determined by the inefficiency of these patents. An alternative solution is to find other tools to increase the volume of innovative products, works, and services in the production and distribution of electricity, gas and water.

At the third stage, in order to provide a targeted approach to the implementation of the proposed method of rationalization of water resources management in industry, 3 types of subjects of the Russian Federation with characteristic features of water use and environmental load are identified. In this regard, at the initial stage of clustering, 3 clusters are set to be allocated. Based on the results of the variance analysis, it should be concluded that clustering was successful, since the significance levels p are less than 0.05, and the differences between the three clusters are significant (Table 3).

|        | Between - SS | Df | Within - SS | df  | F        | signif. - p |
|--------|--------------|----|-------------|-----|----------|------------|
| x1     | 13177270     | 2  | 74267700    | 76  | 6.7423   | 0.002016   |
| x2     | 351157900    | 2  | 52449340    | 76  | 254.4169 | 0.000000   |
| x3     | 2724053      | 2  | 10226960    | 76  | 10.1217  | 0.000127   |
| x4     | 24249530     | 2  | 89988200    | 76  | 10.2400  | 0.000115   |

Thus, as a result of clustering of the subjects of the Russian Federation, 3 types of regions were formed in terms of industrial water use, as well as environmental pollution by the industrial sector of the Russian economy. In Table 4 the classification of regions is presented, as well as those that account for more than 1 % of the total volume of shipments for processing industries in 79 regions of the Russian Federation. Note that this method of research takes into account the scale of the manufacturing industry, since we previously identified the closest relationship between water pollution indicators and this type of economic activity.
Table 4. Typology of constituent entities of the Russian Federation depending on the nature of water use and environmental pollution.

| Cluster | Constituent entities of the Russian Federation |
|---------|-----------------------------------------------|
| 1       | Kursk region; Tver region; Rostov region; Republic of Bashkortostan; Republic of Tatarstan; Saratov region; Sverdlovsk region; Tyumen region; Chelyabinsk region. |
| 2       | Voronezh region; Lipetsk region; Moscow region; Orel region; Smolensk region; Moscow; Vologda region; Leningrad region; Republic of Crimea; Krasnodar territory; Perm territory; Orenburg region; Samara region; Krasnoyarsk territory; Irkutsk region; Kemerovo region; Omsk region; Primorye territory. |
| 3       | Belgorod region; Bryansk region; Vladimir region; Ivanovo region; Kaluga region; Kostroma region; Ryazan region; Tambov region; Tula region; Yaroslavl region; Republic of Karelia; Komi Republic; Arkhangelsk region; Kaliningrad region; Murmansk region; Novgorod region; Pskov region; Saint Petersburg; Republic of Adygeya; Astrakhan region; Volgograd region; Republic of Dagestan; Kabardino-Balkarian Republic; Karachay-Cherkess Republic; Republic of North Ossetia-Alania; Chechen Republic; Stavropol territory; Republic of Mari El; Republic of Mordovia; Udmurt Republic; Chuvash Republic; Kirow region; Nizhny Novgorod region; Penza region; Ulyanovsk region; Kurgan region; Republic of Altai; Republic of Tyva; Republic of Khakassia; Altai territory; Novosibirsk region; Tomsk region; Republic of Buryatia; Republic of Sakha (Yakutia); Trans-Baikal Territory; Kamchatka territory; Khabarovsk territory; Amur region; Magadan region; Sakhalin region; Jewish Autonomous region.; Chukotka Autonomous Area. |

Clusters 1 and 2 are mainly concentrated in large manufacturing regions of the Russian Federation. Descriptive statistics, such as the arithmetic mean (m) and standard deviation (SD), allow us to estimate the nature of clustering parameters for each of the three classification groups (Table 5).

Table 5. Descriptive Statistics for clusters.

| Cluster | Water withdrawal from natural water reservoirs for use, million cubic meters | Recycled and consistent use of water, million cubic meters | Emission of pollutants into atmosphere, thousand tons | Atmospheric pollutants captured and neutralized, thousand tons |
|---------|--------------------------------------------------------------------------------|----------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------|
|         | $x_1$ | SD | $x_2$ | SD | $x_3$ | SD | $x_4$ | SD |
| 1       | 1360.03 | 1305.94 | 7061.97 | 1564.47 | 528.49 | 722 | 1145.33 | 2248.04 |
| 2       | 1290.06 | 1524.19 | 2882.24 | 1055.62 | 443.11 | 577.73 | 1454.54 | 1641.51 |
| 3       | 453.26 | 643.68 | 552.47 | 522.53 | 83.22 | 86.62 | 197.27 | 271.21 |

In Table 5 the maximum average values for each of the clustering parameters are highlighted. It is obvious that the first cluster (11% of the total number of studied regions) combines regions that are industrially developed, consume significant amounts of water, but at the same time have the most negative impact on the environment, taking into account the volume of neutralized pollutants – the cluster "Regions with high water use, actively using recycled water supply, but intensively polluting the atmosphere". The second cluster (23%) covers the subjects of the Russian Federation that intensively use water resources in economic activities, but at the same time implement active measures to capture pollutants – the cluster "Regions with a high volume of water use that pollute the atmosphere, but actively capture harmful substances". The third cluster (66%) includes regions with predominantly low water use and atmospheric pollution-the cluster "Regions with low water use and relatively low air pollution" (Figure 4).
4 Discussion
Thus, the directions of rationalization of water resources management in industry are determined, among other things, by the region's belonging to a particular selected cluster. With regard to water use by subjects of the Russian Federation included in clusters 1 and 2, it is necessary to tighten monitoring of polluting emissions into the atmosphere; subjects of cluster 2 and 3 need to increase the level of recycled water use. Taking into account that construction works are being carried out in all regions in one or another volume, it is recommended to introduce water-saving technologies for each of the three selected clusters in both cases - in the construction of industrial and residential facilities.

Thus, the analytical literature review allows us to summarize that at present research and methods are mainly of a general universal nature. In the works of A. K. Gain et al. the proposed Global water security index (GWSI) aggregates indicators of water availability, quality, safety, and water management for macro systems [13]; in K. J. Aggarwal et al. Water insecurity index WII covers such parameters as water resources, access to water, water use, capacity, environmental component, climate component [16]; The national water security index (NWSI) takes into account household security, economic, urban and environmental security, and resilience to natural disasters as a result of flooding [17], etc. This study presents a set of water management models, which, in contrast to existing methods, is built taking into account the enlarged industries - mining, manufacturing, and energy.

5 Conclusions
As a result of the research, the directions of modernization of the management mechanism of water use in industry are identified and proposed, taking into account the concept of sustainable development.

1) Developed a system of models describing the dependence of water use of sustainable development indicators in the context of industry sectors, which presents ways of rationalizing the use of water resources in Russia: in the mining sector – increase in costs of ICT and the amount of trapped air pollutants; in manufacturing – increasing per capita incomes and reducing unemployment; in the sphere of production and distribution of electricity, gas and water, it is necessary to increase the average per capita income of the population, increase the volume of innovative goods, works, and services, and reduce the use of protected intellectual property results due to their low performance.

2) Regional specifics of water resources use in Russia are revealed. As a result of the cluster analysis, 3 types of constituent entities of the Russian Federation were formed: regions with high volume of water use, actively using recycled water supply, but intensively polluting the atmosphere; regions with high volume of water use, polluting the atmosphere, but actively catching harmful substances; regions with low volume of water use and relatively low air pollution. With regard to water use by constituent entities of the Russian Federation included in clusters 1 and 2, it is necessary
to tighten monitoring of polluting emissions into the atmosphere; subjects of cluster 2 and 3 need to increase the level of recycled water use.

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References
[1] Mitchell G 1996 Problems and fundamentals of sustainable development indicators *Sustain. Dev.* 4 pp 1–11 DOI: 10.1002/(sici)1099-1719(1996034:1<1::aid-sd>3.0.co;2-n.
[2] Dyrdonova A N, Lin’tkova T S 2019 Principles of petrochemical cluster’ sustainability assessment based on its members’ energy efficiency performance *E3S Web of Conferences* DOI: 10.1051/e3sconf/201912404013.
[3] Khusnutdinova S 2011 Policentricity as a way to sustainable development of the city (The case-study of the city of Kazan) International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM pp 621–628 DOI: 10.5593/sgem2017/53/S21.075.
[4] Meshalkin V P, Bobkov V I, Dli M I, Belozersky A Y and Menshova I I 2019 Optimizing the energy efficiency of a local process of multistage drying of a moving mass of phosphorite pellets *Reports of the Academy of Sciences* 486 pp 144–148 DOI: 10.31857/s0869-56524863316-321.
[5] Bobkov V I, Fedulov A S, Dli M I, Meshalki V and Morgunova E V 2018 Scientific basis of effective energy resource use and environmentally safe processing of phosphorus-containing manufacturing waste of ore-dressing bars and processing enterprises *Clean Technol. Environ. Policy.* 20 pp 2209–21 DOI: 10.1007/s10098-018-1633-0.
[6] Malysheva T V, Shinkevich A I, Ostanina S S, Vodolazhskaya E L and Moiseyev V O 2016 Perspective directions of improving energy efficiency on the meso and micro levels of the economy *J. Adv. Res. Law Econ.* 7 pp 75 DOI: 10.14505/jarle.v7i(15).09.
[7] Koh S C L, Morris J, Ebrahimi S M and Obayi R 2016 Integrated resource efficiency: measurement and management *Int. J. Oper. Prod. Manag.* 36 pp 1576–1600 DOI: 10.1108/IJOPM-05-2015-0266.
[8] Lubnina A A, Melnik A N and Smolyagina M V 2016 On modelling of different sectors of economy in terms of sustainable development *Int. Bus. Manag.* 10 pp 5592–95 DOI: 10.3923/ibm.2016.5592.5595.
[9] Smolyagina M V, Lubnina A A 2016 Concerning the environmental marketing of waste management in the context of sustainable development *Int. J. Pharm. Technol.* 8 pp 257–264 DOI: https://doi.org/10.9770/ird.2019.1.4(2).
[10] Bobylev S N, Cheresnyha O Y, Kulmala M, Lappalainen H K, Petäjä T, Solov’Eva S V, Tikunov V S and Tynkynen V P 2018 Indicators for digitalization of sustainable development goals in peex program *Geogr. Environ. Sustain.* 1 pp 145–156 DOI: 10.24057/2071-9388-2018-11-1-145-156.
[11] Cook C, Bakker K 2012 Water security: Debating an emerging paradigm *Glob. Environ. Chang.* 22 pp 94–102 DOI: 10.1016/j.gloenvcha.2011.10.011.
[12] Mounen Z, El Idrissi N E A, Tvaronavičienė M and Lahrach A 2019 Water security and sustainable development *Insights into Reg. Dev.* 1 pp 301–31
[13] Gain A K, Giupponi C, Wada Y 2016 Measuring global water security towards sustainable development goals *Environ. Res. Lett.* 11 DOI: 10.1088/1748-9326/11/12/124015.
[14] Wutich A and Ragsdale K 2008 Water insecurity and emotional distress: Coping with supply,
access, and seasonal variability of water in a Bolivian squatter settlement Soc. Sci. Med. 67 2116–25 DOI: 10.1016/j.socscimed.2008.09.042.
[15] Aihara Y, Shrestha S, Kazama F and Nishida K 2015 Validation of household water insecurity scale in urban Nepal Water Policy 17 pp 1019–32 DOI: 10.2166/wp.2015.116.
[16] Aggarwal S, Punhani G K J 2014 Hot Spots of Household Water Insecurity in India’s Current and Future Climates: Association with Gender Inequalities. wH2O J. Gend. Water. 3
[17] Asian Water Development Outlook 2016. Strengthening Water Security In Asia And The Pacific 2016 (Philippines: Asian Development Bank) p 136
[18] Shrestha S, Aihara Y, Bhattarai A P, Bista N, Kondo N, Futaba K, Nishida K and Shindo J 2018 Development of an objective water security index and assessment of its association with quality of life in urban areas of developing countries SSM - Popul. Heal. 6 pp 276–285 DOI: 10.1016/j.ssmph.2018.10.007.
[19] Morris J 2019 Developing and exploring indicators of water sustainable development Heliyon 5 DOI: 10.1016/j.heliyon.2019.e01778.
[20] Zhang D D, Chang L, Wu S C, Cui Y Q, Wang Y S and Zeng J J 2019 Study on sustainable development of water resources in Gansu Province IOP Conf. Series: Earth and Environmental Science DOI: 10.1088/1755-1315/344/1/012164.
[21] Yang G, He X and Li J 2010 The Evaluation Method Study for Water Resources Sustainable Utilization in Arid Areas Int. J. Chem. Eng. Appl. 1 pp 359–362 DOI: 10.7763/ijcea.2011.v2.91.