Research in Marine Sciences
Volume 5, Issue 1, 2020
Pages 655 - 668

Normalization and determining optimal levels of environmental indicators - case study: National Iranian Oil Companies (sustainable development approach)

Zaynab Erfani[1,*], Seyed Mohammad Taghi Sadatipour[2], Hossein Ghaforian[1], and Ebrahim Alaei[3]

[1]Department of Environmental Engineering, Faculty of Marine Science & Technology, Islamic Azad University, North Tehran Branch, Tehran, Iran.

[2]Department of Coastal Approach with Sustainable Attitude, Faculty of Marine Science and Technology, Islamic Azad University, North Tehran Branch, Tehran, Iran.

[3]Department of Ecology, Faculty of Biology, University of Tehran, Tehran, Iran.

Received: 2019-11-28 *Accepted: 2020-03-05*

Abstract

Most of Oil companies' pollutants have a cumulative nature and trustee agencies have not defined any standard levels in Iran. This paper deals with the determination of the extent of overlap between environmental indicators in the Iranian National Oil Companies with other similar major oil companies and organizations in the world and how sustainable development could be achieved. To achieve sustainable development it would be better to use the optimal level of these indicators that can be determined using normalization methods. For this purpose, three-year environmental performance data from 15 upstream companies and subsidiaries were considered. For calculations of optimal levels, oil-producing companies were selected and data were normalized at the production scale. Determining the overall levels provided the knowledge of achieving optimal marginal levels and critical points. Finally, the data were standardized through the maximum and minimum normalization method, based on the average of marginal overalls.

Keywords: Environmental Indicators; National Iranian Oil Company (NIOC); Sustainable Development; Overall levels; Optimal marginal levels.

*Corresponding Author email: zeynaberfani1360@gmail.com

1. Introduction

Different stages of oil exploration and production in upstream and downstream oil industries have various effects on the environment. The basic principle of paying attention to the needs of future generations has encouraged and required oil and environmental specialist to take measures and provide solutions for control and reduce the negative environmental impacts caused by these industries. To this end, a wide range of environmental indicators are currently being used that like signs specify the path. Usually, more than one indicator is used to ensure conclusions and show that the probability of errors is minimized (Dong and Hauschild, 2017). Environmental indicators are essential tools for policymakers. These indicators reflect the state of environment and how to monitor the progress made towards achieving environmental goals and policies. The need to pay attention to the environment in the oil industry and affiliated industries become clearer when we realize that it is not possible to move in the direction of continuous industrial improvement regardless of environment (Smeets and Weterings, 1999). One of the principles of a sustainable development strategy is to eliminate or reduce the harmful effects of the pollutants of these industries to an acceptable level. In short, the strategy can be summarized as follows: "A guide to move from the current state to the desired state". Progress-based sustainable development has three economic, social and environmental contexts. In this study, the environmental contexts will be examined. So what is certain is the need to develop environmental strategies and include them in the planning of oil exploration and production industries. The use of criteria, standards and benchmarks that can express the environmental sustainability quantitatively has always been considered as one of the main issues and concerns of planners, politicians and researchers, and is now paid attention by many scholars. However, studies have been to the extent that they have only referred to the necessity of moving towards sustainable development and obtaining these acceptable levels in various industries. To date, no studies have been carried out in this regard at the National Iranian Oil Company (NIOC), and these levels are not defined for environmental indicators in industries with pollutants of a cumulative nature, including the NIOC.

Pourasghar Sangachin *et al*. (2010) examined the structure of sustainability and environmental performance indicators (EPIs) over different periods. The results of their study indicated that only due to the fundamental differences between these indicators, it cannot be said that whether the environmental status of Iran has been upgraded or degraded among the countries of the world. The results of their study suggested the necessity of promoting environmental indicators and correctly publishing the reports on environmental activities of the country. In a study by Sahebi *et al*. (2014), an environmental plan for the crude oil chain was presented, the results of which showed that there is no consensus on a global measure of environmental sustainability. In a review study by Gaudencio *et al*. (2018), sustainability reports from four oil companies in Brazil since 2015 were analyzed. Their study results revealed to what extent the development of a system of indicators more capable of measuring the performance of environmental sustainability of oil companies, especially at the level of operating units is necessary. Alazzani and Wan-Hussin (2013) emphasized the use of a standard evaluation system for environmental reports to reduce the damage caused by oil and gas companies in developing countries. However, having a common unit of measurement for comparing and combining indicators is necessary. This process is achieved by scaling and normalizing the data. Normalization acts as a necessary step to achieve the similar scales or unit-less measures. Kiavarz Moghadam (2019) suggested that in the sustainable development topics, the main motive for normalization is to convert measurements of indicators with different units into a common measurement unit to compare them. Normalization has different meanings in statistics, the simplest of which is a method for inserting data in the same domain, when they are not in a domain. Therefore, each of the studies in this field has somewhat emphasized on measuring the achievement of sustainable development, using appropriate criteria and methods. The main questions of the study is by which tools the mentioned methods can be determined and whether it is possible to obtain the optimal and standard levels for studying the achievement of sustainable development using the normalization method. Therefore, in light of the strong recommendations made in the studies on the correct publication of reports on environmental activities in terms of comparability with other international assemblies, the determination of a method that can scale environmental indicators data using appropriate criteria was one of the requirements of this study.

2. Materials and methods

This was a case study conducted at the level of companies in which the HSE management of the National Iranian Oil Company (NIOC), as an upstream manager, directly monitors their environmental performance assessment, crises identification, environmental incidents, policy-making, planning, and necessary training (Ministry of Petroleum, 2018). In order to conduct the study, the performance statistics of eight environmental indicators from 15 subsidiaries of the NIOC HSE Management from 2014 to 2018 were collected. The data were selected according the maximum available and sufficient information for analysis. The data of 2017 and 2018 had high deficits due to changes in management, deletion and addition of indicators, etc. Therefore, they were excluded from this study and the data of 2014 and 2015 with the highest accuracy and reliability were selected as pilot. Also, the data in eight groups of environmental indicators including gases burned in million cubic meters, industrial waste water produced in cubic meters, industrial waste produced in tons, the rate of oil inflow in barrel, the rate of oil inflow in item, the rate of accidental gas emissions in cubic meter, the rate of accidental gas emissions in item, and amount of green space added were reported. Data were collected through inquiries of related experts and companies (Table 1). Interviews and consultations with professors, professionals, experts, specialized resources, web searches and the common sense were also used for scientific reviews and data accuracy. One of the main parts for assessing sustainable development is the environmental assessment, which relies on various environmental indicators measured and reported over time. The environmental performance of subsidiaries of the NIOC HSE Management was evaluated through the eight indicators has mentioned above (2014 to 2018). Due to the fact that most of these pollutants have a cumulative nature, no standard level is defined for them by trustee agencies. So this study was conducted aimed at determining the optimal levels for these environmental indicators with a sustainable development approach. Firstly, in order to model the correct reporting of environmental sustainability in the world, as well as how to create the data comparability with other international assemblies, the overlap between the 15 subsidiaries studied, 6 companies and 3 major oil companies in the world [Sinopec Corp (2018), PetroChina (2017), Shell (2018), BP (2017), Exxon Mobil (2010), Total, IOGPa (2018), API, IOGA and IPIECA (2015), IPIECA (2018), API and IPAA(2018)] in terms of the type of activity and environmental performance indicators was investigated. For this purpose, subsidiaries were numbered (in the written texts of this study, they were referred to with the numbering conducted), then they were examined based on their mission and type of activity and divided into four groups of production, service project-based and drilling as follows. Production companies: Companies No. 1, 3, 4, 7 and13, service companies: Companies N0. 5, 6, 8, 10 and 12, project-based companies: Companies N0. 9, 14 and15, and drilling companies: Companies No. 2 and 11. The main activity of production companies was oil production, and service companies were those, for example, with the task of oil export. Project-based companies were responsible for managing and overseeing the implementation of huge oil projects at the NIOC, and drilling ones undertook drilling operations for oil wells. It was found that there is the most overlap between subsidiaries and OGP subsidiaries according to their type of activity and their specific indicators (IOGPb, 2018). Therefore, the environmental sustainability of the organization was determined using the reporting method. Performance data Normalization using comparable criteria such as oil production, the amount of water with oil and relative averages can be a fundamental solution. Oil production data were selected as the comparable criterion and data relative averaging in order to use comparable criteria and data relative averaging, because only production companies had the capability of generating oil production data, and only these data were available and collectable. Subsequently, the environmental performance data of the production companies (No. 1, 3, 4, 7 and 13) were used for research purposes. According to the latest reports and inquiries collected, the crude oil production capacity of the NIOC is equal to 3,940,000 thousand barrels per day (ISNA News Agency, June 2019), of which about 2,950,000 barrels is produced by Company No.1, 210000 barrels by Company No. 3, 400000 barrels by Company No. 4, 20000 barrels by Company No. 7, and finally 360000 barrels by Company No. 13 (Nasim Online, 2019). The environmental performance data of the production companies in the years studied were scaled in level of oil production and in the unit of thousand barrels per day (production unit) by mathematical calculations. The calculation was based on the dividing each environmental performance data into the oil production unit of the relevant company, that are presented in Table 2. The sustainability assessments often rely on different indicators, so having a common unit of measurement for comparing and combining indicators is necessary. This process can be called scaling. Indeed, when indicators units are different, scaling is used as an essential step to achieving similar scales or unit-less measures, and becomes a tool for measuring the marginal levels of pollutants production by creating comparable bases (Munda and Nardo, 2005), which is used for research purposes. In the next step, in order to allow the performance data normalization, after scaling the data in the production unit, the range of data changes was estimated by means of relative averaging of each of the indicators in each of the studied years (Ural) (Table 3). However, due to the outliers caused by various factors such as

Table 1. Raw data

Years	Company name	Company number (no)	Daily oil production (barrels)	Burned gases (million cubic meters)	Industrial waste (m^3)	Industrial waste (tons)	Oil inflow (items)	Oil inflow (barrels)	Accidental gas emissions (items)	Accidental gas emissions (cubic meters)	Green space added (m^2)
2014	NISOC	1	22950	224.2	885079	45	4	188	3	18	2
2015	NISOC	1	22950	189.6	698254	349	4	20	3	8	2
2016	NISOC	1	22950	224.2	773395	439	6	201	2	4	2
2014	ICOFC	3	2210	98.6	7467	64	1	18	0	1	96
2015	ICOFC	3	2210	74.2	5403	93	0	38	0	6	2
2016	ICOFC	3	2210	151.3	6890	84	0	11	0	1	471
2014	IOOC	4	4400	444.3	1139781	285	0	57	0	0	2
2015	IOOC	4	4400	364.7	1370263	334	0	4	0	0	6
2016	IOOC	4	4400	413.5	1472198	346	0	17	0	0	1
2014	POGC	7	220	243.3	9788	1301	0	0	0	0	2
2015	POGC	7	220	143.8	35504	941	0	0	0	0	2
2016	POCG	7	220	180.8	66421	471	0	0	0	0	853
2014	AOGC	13	3360	25.4	6196	21	0	0	0	0	0
2015	AOGC	13	3360	27	8621	2	0	1	0	0	0
2016	AOGC	13	3360	67.5	6348	0	0	16	0	0	0

Table 2. Scaled data per unit of oil production

Years	Company name	Company number (no)	Burned gases (million cubic meters)	Industrial waste (m^3)	Industrial waste (ton)	Oil inflow (items)	Oil inflow (barrels)	Accidental gas emissions (items)	Accidental gas emissions (cubic meters)	Green space added* (m^2)
2014	NISOC	1	300.026	0.0152	0.001	0.063	0.001	0.006	0.0006	-
2015	NISOC	1	236.69	0.118	0.001	0.006	0.001	0.002	0.0006	-
2016	NISOC	1	262.16	0.148	0.002	0.068	0.0006	0.001	0.0006	-
2014	ICOFC	3	35.55	0.304	0.004	0.085	0	0.004	0.4577	-
2015	ICOFC	3	25.72	0.442	0	0.180	0	0.028	0.0095	-
2016	ICOFC	3	32.80	0.4	0	0.052	0	0.004	2.2428	-
2014	IOOC	4	2849.45	0.712	0	0.142	0	0	0.005	-
2015	IOOC	4	3425.65	0.835	0	0.01	0	0	0.015	-
2016	IOOC	4	2310	15	0	0	0	0	9	-
2014	POGC	7	489.4	65.05	0	0	0	0	0.1	-
2015	POGC	7	1775.2	47.05	0	0	0	0	0.1	-
2016	POGC	7	3321.05	23.55	0	0	0	0	42.65	-
2014	AOGC	13	17.21	0.058	0	0	0	0	0	-
2015	AOGC	13	23.94	0.005	0	0.002	0	0	0	-
2016	AOGC	13	17.63	0	0	0.044	0	0	0	-

*Due to the disproportionality of the green space index with the scale of oil production, calculations were not performed on the data of this index.

operator errors, visual errors, and errors resulting from the removal and addition of some companies and their ownership, there was still no correct understanding of the data comparisons. According to the studies, the maximum-minimum normalization is used to establish the accuracy of the concepts and data comparisons by eliminating the impact of these factors. Therefore, according to the purpose of the research, Min-Max normalization method was used for data normalization, and they were normalized using the following equation (Table 4).

Max A = the largest data in the data range

Min A = the lowest data in the data range

new_maxA = 1

new_minA = 0

V = input data

Finally, in order to achieve the goals, the data were standardized on the basis of the overalls average. Standardization is a technique after the data normalization, and after the normalized data output is a value between zero and one. Then, for standardization, the average Ural of three years of each index (X) is as follows which s is the standard deviation. The values are given in Table 5.

$$\frac{X - mean}{s} \quad \text{or} \quad \frac{X - min}{max - min}$$

3. Results and Discussion

According to the results of normalization mean the data scaling in the oil production unit, when the units of the indicators are different, scaling is as an essential step to achieving similar scales or unit-less measures, including the correct analysis of data and measuring the marginal levels of the pollutants production. These findings were consistent with the findings of the study by Munda and Nardo (2005). The determination of the relative averages or the same overalls for each index per year provided the knowledge of achieving the maximum and minimum levels of variation in the production range of pollutants (indices). This was also in line with the results of the study by Kiavarz Moghadam (2019) the results of which on the index of burned gases were presented in Figure 1. This study also indicated that by creating the

Table 3. Data relative average (overalls) for each index per year

Years	Burned gases (million cubic meters)	Industrial waste (m^3)	Industrial waste (ton)	Oil inflow (items)	Oil inflow (barrels)	Accidental gas emissions (items)	Accidental gas emissions (cubic meters)
2014	2.7	738.3	13.2	0.0012	0.057	0.0002	0.0021
2015	1.7	1097.4	9.6	0.00027	0.039	0.0002	0.0061
2016	2.2	1462.8	4.9	0.00041	0.041	0.00014	0.0012

Table 4. Normalized data by min-max normalization method (average data for years)

Company name	Burned gases (million cubic meters)	Industrial waste (m^3)	Industrial waste (ton)	Oil inflow (items)	Oil inflow (barrels)	Accidental gas emissions (items)	Accidental gas emissions (cubic meters)
NISOC	0	0.0747	0.0015	0.9978	0.4342	1	0.2714
ICOFC	0.0466	0.0035	0.0079	1	1	0	1
IOOC	0.1003	1	0.0169	0	0.6065	0	0
POGC	1	0.5584	1	0	0	0	0
AOGC	0.0041	0	0	0	0.1471	0	0

Table 5. Standardized data (critical points) based on the average overalls per year

	Burned gases (million cubic meters)	Industrial waste (m^3)	Industrial waste (ton)	Oil inflow (items)	Oil inflow (barrels)	Accidental gas emissions (items)	Accidental gas emissions (cubic meters)
Average overalls per year	2.2	1099.5	9.23	0.00062	0.137	0.00018	0.0031
Critical points	0.22	0.32	0.20	0.4	1.29	0.19	0.25

accuracy in the concepts and data comparisons through eliminating the impact of limiting factors using research methods, it was possible to determine production levels of indicators to assess the achievement of sustainable development using normalization methods (including min-max normalization) (Figure 1). In addition, normalization analysis suggested that the average of the overalls per year provided the knowledge of achieving critical points (optimal levels) through data standardization. It could also be used to assess the achievement of sustainable development, the results of which are shown in Figures 2-6.

Figure 1 indicated that the analysis of the production rate of each pollutant (index), for example, burned gases, is only possible in terms of increasing or decreasing production per year, and there is no standard measure for this. Therefore, the determination of overalls each year indicated, for example, the variation in the production range of the index of burned gases in production companies from 0.2 to 0.4 million cubic meters of gas burned per unit of production. Also, according to the above figure, it was found that with respect to the

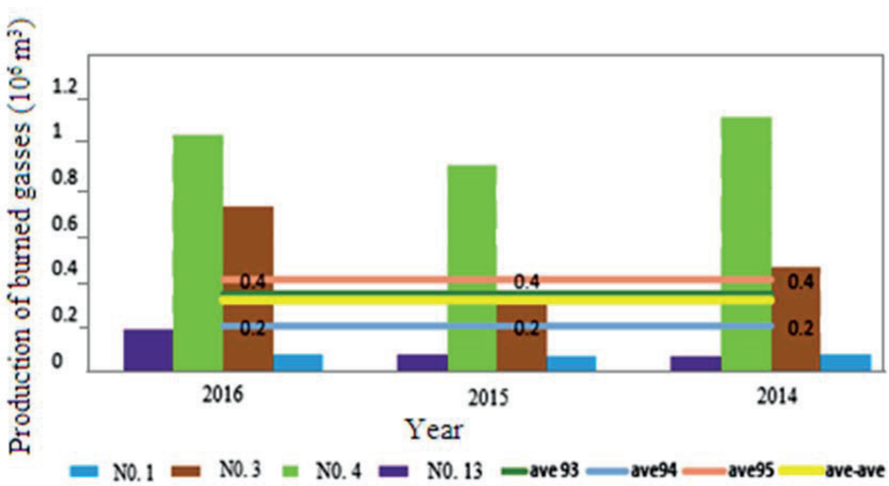

Figure 1. Marginal levels (overalls) for the production of burned gasses (10^6 m^3)

range of variations and marginal levels of data production, there is no fixed level to examine the reduction of these pollutants production toward eliminate and becoming zero (sustainable development), or the strategy of "the current state to the desired state".
The results of determining the optimal levels for each index examined after normalization and the standardization of normalized data, using the average overalls per year, were shown in the following figures as critical point, respectively. The degree of deviation from these critical points determines the degree of deviation from the path to industrial sustainable development. For example, in Figure 2, the Company No.7 should consider at least 15% burning reduction per year in order to move towards sustainable development over the next 5 years.
Regarding the green space index, because of the impossibility of performing the steps and methods of the study on it (due to the impossibility of scaling to normalize the data), its raw data per year were collected and shown in Figure 7. The impossibility of interpreting the index was well represented. Also, the impossibility of determining the optimal level for this index was another evident and important point of the study.
Also, in order to indicate the necessity of this study, the reported crude data for the burned gases index, along with the data processed by the methods and the analysis of normalization

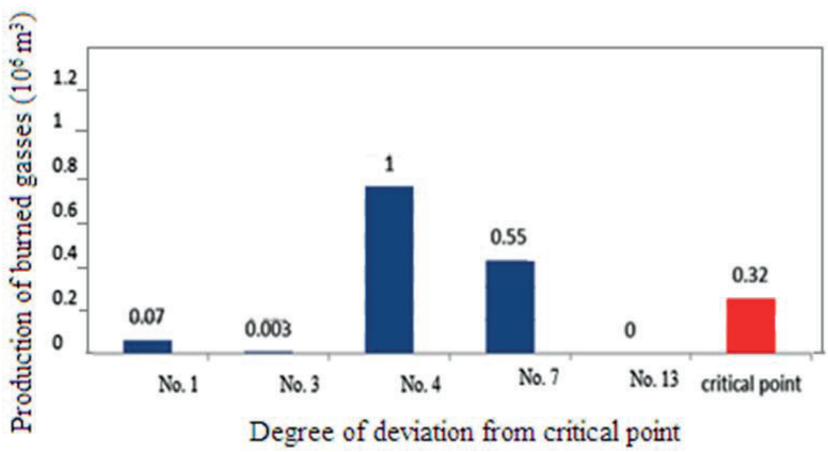

Figure 2. Degree of deviation from critical point for gas burned per production unit

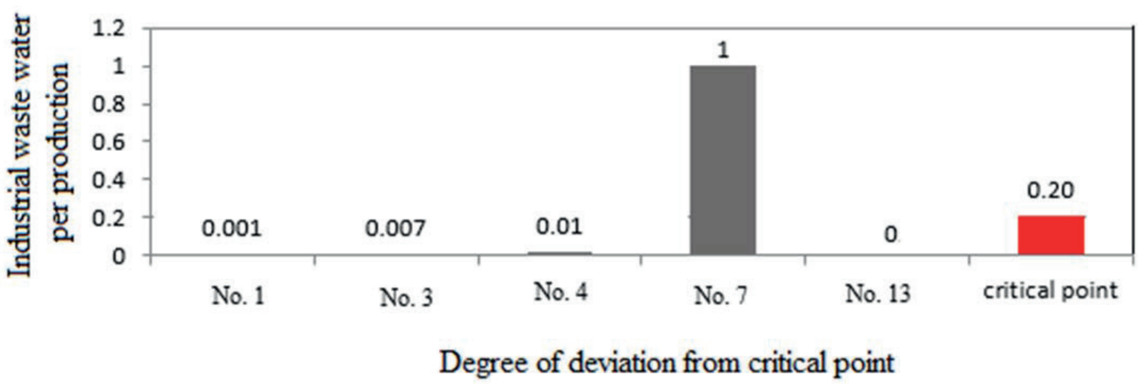

Figure 3. Degree of deviation from critical point for industrial waste water per production unit

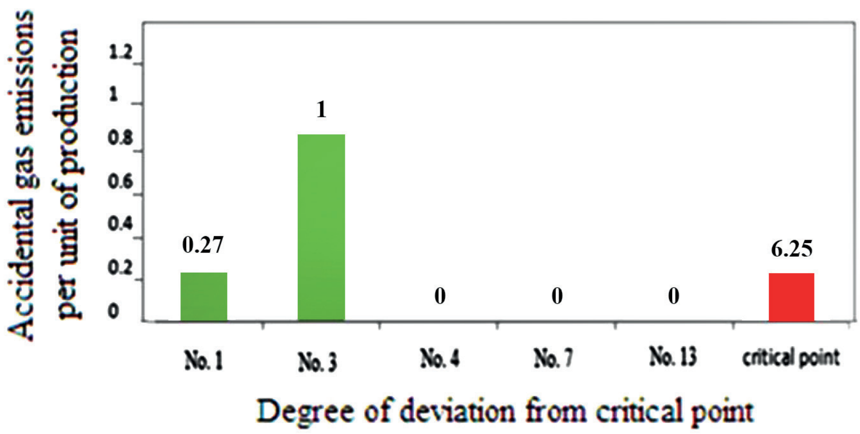

Figure 4. Degree of deviation from critical point for accidental gas emissions per unit of production

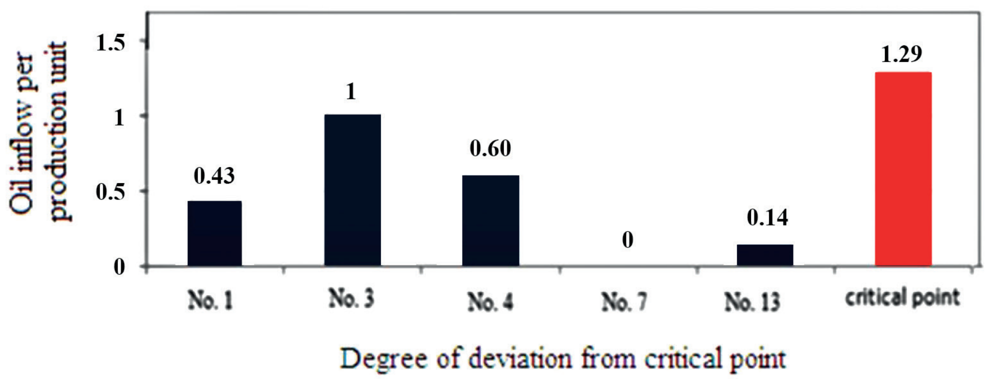

Figure 5. Degree of deviation from critical point for oil inflow per production unit

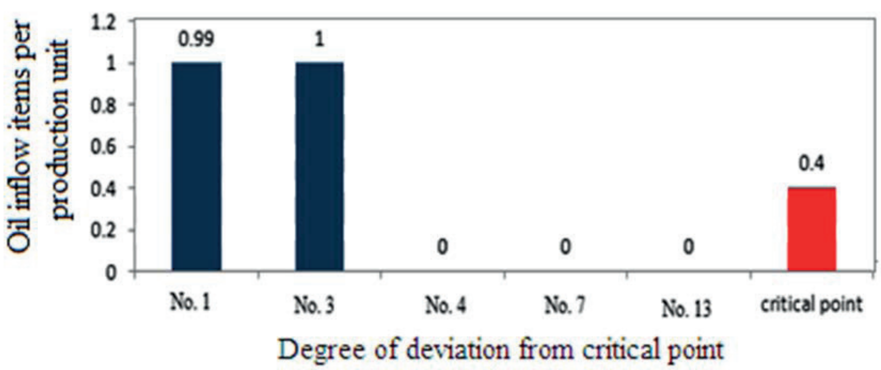

Figure 6. Degree of deviation from critical point for oil inflow items per production unit

calculations, were shown in Figures 8 and 9. As it is evident in figures, before data processing by the mentioned methods, for example, the Company No. 4 had the highest level of gas burning at the level of production companies. However, after data processing the highest value belonged to company No. 7.

Figures 8 and 9 illustrated a visible difference

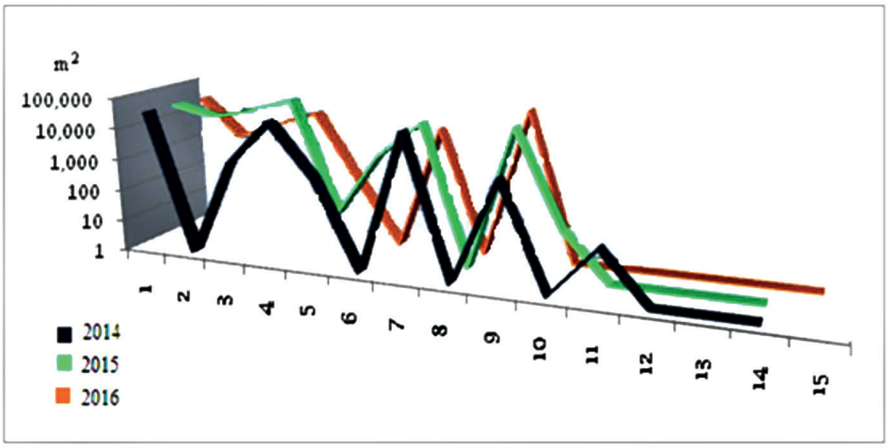

Figure 7. The amount of green space added during the years 2014, 2015 and 2016 at the level of the NIOC

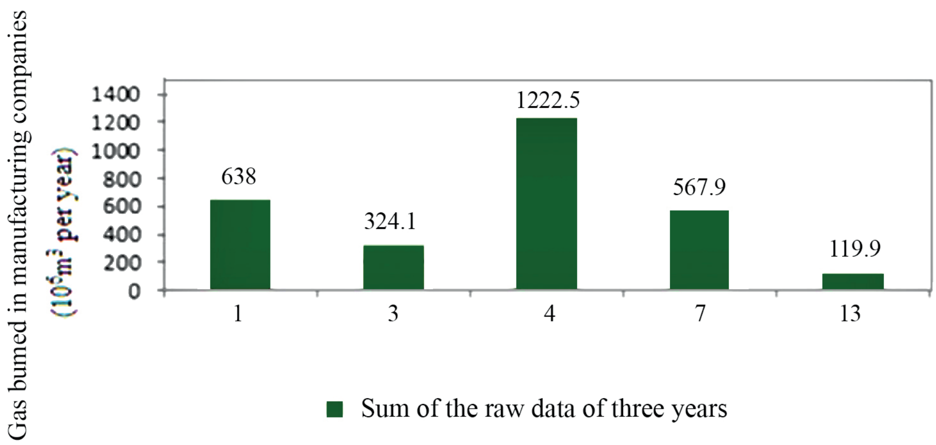

Figure 8. Gas burned in manufacturing companies ($10^6 m^3$ per year), before data processing

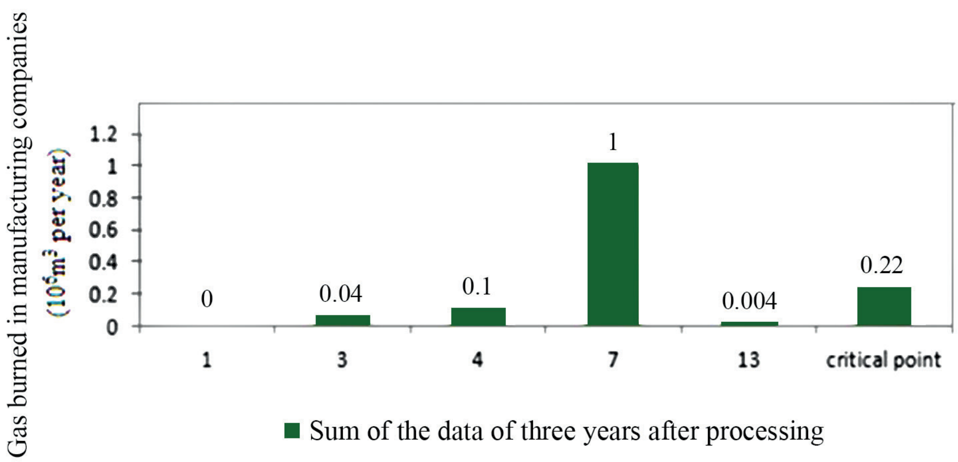

Figure 9. Gas burned in manufacturing companies ($10^6 m^3$ per year), after data processing

in the results before and after the study, highlighting the importance of performing it. This was consistent with the results of the study conducted by Azadeh *et al.* (2017).

Conclusion

Environmental performance data of the subsidiaries of the NIOC HSE Management were normalized to determine the optimal and standard levels of indicators that, due to their cumulative nature no standard has been defined for them by trustee organizations. The results indicated that normalization, meaning data scaling though making them significant and elimination of data errors, and integrating the data review criterion, provided the conditions for proper analysis and obtaining the correct results. For example, regarding the gas burning index, The results indicated the data errors resulting from irregular, illegible and inaccurate company reports, the lack of similar measurement systems or their inadequacy, the insignificance of indicators for some companies, the weakness of the human resources, the lack of awareness of some agencies of the production rates, lack of awareness of how to estimate the index, not passing data sent from an administrative channel, and lack of systematic order for collecting and sending data.

On the other hand, based on the results of the application of the study methods, the use of normalized data at the oil production scale made it possible to determine the relative averages (overalls) of each year in order to estimate the production rate of the indicators and thus to assess the extent to which sustainable development was achieved. This was in line with the results of the study by Kiavarz Moghadam (2019). Additionally, the results indicated that standardization of the normalized data can be achieved using normalization methods (including min-max normalization), and ultimately, the determination of the optimal levels of environmental indicators and the assessment of the sustainable development approach will be feasible. This can cause a huge change in the plans and policies of the NIOC and lead its polluting processes to reduce production and achieve sustainable environmental development, in the case of using a longer period of time (more years) and having more accurate and more reliable data.

Other results indicated that normalized data may themselves be affected by factors such as a change in the company's ownership list, the dissolution or change of its properties, and even its assets. So it was found that even if the coverage of the environmental activities of companies is good, the changes in the results do not necessarily reflect the actual changes in performance. The study suggested that, with at least 3 years of continuous reporting on the quantity of indicators, the challenges in the quality of indicators, how to report and collect data, how to process, how to analyze and how to move towards sustainable environmental development can be found. According to the results, in companies with a higher coverage rate, for example, in Company No. 1, with a high percentage of hydrocarbon production, information can be considered as approximate performance of the industry. Other results indicated that normalization can be analyzed only when the criteria (pollutants, discharges, and leaks) are normal, and hydrocarbon production data and other baseline data are available depending on the type of index. When evaluating any management system and sustainability evaluations, the results should be as quantitative as possible. Criteria such as data normalization were needed to validate the comparison between subsidiaries and, more generally, the oil industry with other companies and organizations by using them, and, ultimately, to provide decision makers with a comprehensive evaluation system through the defined levels, so that they can take positive steps towards building a sustainable society. Figure 8 illustrates the importance of the study in facilitating analyzes and interpreting and evaluating using standard criteria. Following are some suggestions:

1- Studies have shown that the establishment of a process-oriented approach to the determination of normalization indicators and measures and reports on the environmental performance of the NIOC HSE management subsidiaries, as well as the identification of owners and operators of the processes leading to the production of environmental pollutants and earning their comments, provide the most relevant environmental indicators and measures specific to the NIOC.

2- Creating a reliable information platform to prioritize processes for continuous environmental improvement

3- Determining the scale of data analysis in non-production companies by type of activity

Acknowledgment

We appreciate the research and technology management of the National Iranian Oil Company for its supports.

References

Alazzani, A., and Wan-Hussin, W. N. 2013. Global Reporting Initiative's Environmental Reporting: A Study of Oil and Gas Companies. – Ecological indicators, 32: 19-24.

API, IOGA, and IPIECA. 2015. Oil and Gas Industry Guidance on Voluntary Sustainability Reporting (3rd Edition).

API, and IPAA. 2018. About API. Who We Are. Retrieved from https://www.api.org/about.

Azadeh, A., Shafiee, F., Yazdanparast, R., Heydari, J., and Fathabad, A.M. 2017. Evolutionary Multi-objective Optimization of Environmental Indicators of Integrated Crude Oil Supply Chain under Uncertainty. – Journal of cleaner production, 152: 295-311.

BP (Sustainability Report). 2017. How will BP Respond to Global Change.

Dong, Y, and Hauschild, M. 2017. Indicators for Environmental Sustainability, Research Gate.

Exxon Mobil. 2010. Taking on the world's toughest energy challenges. Corporate Citizenship Report.

Gaudencio, L. M. A. L., de Oliveira, R., Curi, W. F., Santana, C. F. D., Silva, J. N., and Meira, C. M. B. S. 2018. Oil and gas companies operating in Brazil adhere to GRI-G4 essential sustainability indicators: a critical review. Environment, Development and Sustainability, 1: 1-22.

ISNA News Agency. 2019. Energy Categories, Website: https://en.isna.ir/, Retrieved: 2019-06-15.

IOGPa. 2018. About IOGP. Retrieved from https://www.iogp.org/blog/press-releases/eu-pr/low-carbon-hydrogen-can-only-strengthen-linz-initiative/.

IOGPb. 2018. Description. Retrieved from https://www.iogp.org/bookstore/product / environmental-performance-indicators-2016-data/.

IPAA, 2018. About IPAA, Retrieved from https://www.ipaa.org/about/.

IPIECA, 2018. International Petroleum Industry Environmental Conservation Association (IPIECA), Description, Retrieved from http://climateinitiativesplatform.org/index.php/International_Petroleum_Industry_Environmental_Conservation_Association (IPIECA).

Kiavarz Moghadam, M. 2019. Normalizing land surface temperature for environmental parameters in mountainous and urban areas of a cold semi-arid climate. Sci Total Environment.

Ministry of Petroleum, 2018. Subsidiaries of the National Iranian Oil Company, HSE Management, taken from the website.

Munda, G., and Nardo, M. 2005. Constructing consistent composite indicators: the issue of weights, EUR 21834 EN: 1-11.

Nasim Online. 2019. Subdivision of Economy, Oil, Gas, and Petro-chemistry, Retrieved from the website: https://www.nasimonline.ir/, 2019-06-17.

PetroChina (Company Limited). 2017. Sustainability Report 2017.

Pourasghar Sangachin, F. Salehi, A., and Masnavi, M. R. 2010. A Comparative-Analytical Study of Sustainable Development Measurement Methods, Environmental Researches, 1 (1): 67-82.

Sahebi, H., Nickel, S., and Ashayeri, J. 2014. Environmentally conscious design of upstream crude oil supply chain. Industrial & Engineering Chemistry Research, 53(28): 11501-11511.

Shell. 2018. Environmental data. Retrieved from https://www.shell.com/sustainability/sustainability-reporting-and-performance-data/performance-data/environmental-data.html (11/9/2018).

Sinopec Corp, 2018. Key Performance Indicators; Environmental Performance, Retrieved from http://www.sinopec.com/listco/en/environment_society/kpi/.11/24/2018.

Smeets, E., and Weterings, R. 1999. Environmental indicators: Typology and overview (No.19). Copenhagen: European Environment Agency: Denmark.