



Environmental impact assessment of cement industries using mathematical matrix method: case of Ghayen cement, South Khorasan, Iran

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Abstract

Cement industries produce millions of tons of by-products each year, including dust, toxic gases, and heavy metals, which pose respiratory health hazards and environmental pollution. Although several literatures have investigated environmental impact in cement factories, the extent to which these assessments affect the population has received limited responsiveness. This study investigates this gap by examining the environmental impacts of the Ghayen Cement Industry on environmental components and public health. Using a mathematical matrix, it found that the effect of the cement factory on the environment produced four categories of significant effects: L, low; M, medium; H, high; and VH, very high. Results in terms of basic criteria revealed 0.70 of the most destructive effect was related to water pollution. Regarding the interaction effect of project activities (basic and complimentary basic criteria) on environmental components, the highest destructive effect was excavation and land deformation while the lowest effect was on public health. The study also found out that the use of compensation factors reduced the negative effect of the project on the environment. The use of common methods of environmental improvement such as erosion control, proper location of facilities, and the creation of green spaces is essential to mitigate the impact of projects on the environment.

Keywords Environmental impact assessment · Compensation factor · Cement · Mathematical matrices · Iran

Introduction

The growth of industries has triggered growing energy consumption and the emission of pollutants with detrimental effects on both human health and the environment. This situation

has resulted in extensive global environmental threats to human health comprising toxic wastes, emission of toxic gasses, environmental degradation, and climate change. The production of cement, for example, generates a considerable amount of environmentally detrimental carbon dioxide (CO₂). According to Dhoble (2013), the average intensity of CO₂ emissions from total global cement production is 222 kg of C/t of cement. However, life cycle assessment (LCA) studies have been introduced on how to mitigate the emissions of greenhouse gases from the cement industry (Ali 2014; Ali et al. 2016; Wang et al. 2018). Environmental concerns are, therefore, one of the most appropriate fields of improvement because they bring natural and social spheres together. These concerns have serious short- and long-term effects on the population. National development policies and transnational investments in large-scale development projects have also contributed to the increase of different human activities. Duarte et al. (2007), for example, noted that the lack of environmental education, control, and monitoring is one of the major causes of environmental degradation. National governments worldwide have been encouraged in developing environmental policies to protect and enhance sound environmental management

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(Department of the environment (DoE 2017)). A typical example worth emulating is the case of India which introduced environmental impact assessment (EIA) and relies on the institutional framework with strong supporting legislative, administrative, and procedural setup (Ritu 2006). The responsibilities of its development and management are shared by both the central and provincial authorities.

In view of mitigating the effects of huge developmental projects on the environment, it is necessary to balance, coordinate, and order the components of nature for environmental sustainability. International development organizations and regional and national governments have, therefore, recommended environmental impact assessment (EIA) as an important tool to evaluate environmental impacts and development strategies (Drayson et al. 2017). EIA refers to a systematic identification and evaluation of the impacts of projects, programs, and plans on the biophysical, chemical, cultural, and socio-economic components of the environment to avoid negative outcomes (Ott et al. 2012; Da Silva Dias et al. 2019). EIA also examines the effects of diverse human activities and designs on the environment. It is, therefore, imperative to conduct EIA on major projects to limit the effects on the environment particularly because of the long lapse rate of environmental rejuvenation (Duarte et al. 2007; Hatami-Marbini et al. 2013). It has been argued that public participation in the different stages of EIA and decision-making processes is essential for the success of developmental projects (Lockie et al. 2008). When communities participate in aspects that concern them, relationships with institutions and public officials are created which enables them to raise their concerns and gives them a sense of responsibility which is essential for success and sustainability (Pagatpatan and Ward 2018; Tantoh and Simatele 2018). This success to a greater extent depends on the type, nature, and processes used (Hasan et al. 2018). However, the legal basis for EIA in Iran, for example, is an aspect in the National Development Plan (NDP) with a centralization of supervision and screening processes which excludes potential participation and contribution from other stakeholders (Khosravi et al. 2019). This centralization and top-down management processes are time-consuming and full of inefficiencies (Tantoh et al. 2019). Public participation in social and economic impact assessment, therefore, increases awareness and understanding of how a range of other social, demographic, and economic factors can interact to magnify negative impacts (Rolfe et al. 2005; Pagatpatan and Ward 2018; Tantoh and Simatele 2018). However, most governments and industries have seldom involved these affected parties in decision-making processes (Lockie et al. 2008).

An international approach to solving environmental problems and the dynamics of the socio-economic and political developments within the borders has led to the expansion of studies that require structured planning at national and regional levels (Monavari 2005; Drayson et al. 2017). Researchers

have, thus, shown increased interest in methods and application of EIA: cost-benefit (West man 1985), rapid impact assessment matrix (Pastakia and Jensen 1998), fuzzy logic (Salehi 2012), interactive effects questionnaire and listometry check (Panahandeh et al. 2013), multi-criteria evaluation method (Rudgarmi 2007), mathematical matrix and geographic information system (Salehi et al. 2012), the midpoint and endpoint methods (Blankendaal et al. 2014), and life cycle assessment (LCA) (Ali et al. 2016; Wang et al. 2018). Cement factories in Egypt, for example, have been instructed to develop an environmental policy to protect and enhance the quality of ambient air quality (Brown et al. 2014; DoE 2017). Furthermore, The rapid impact assessment matrix (RIAM) method has also been used to evaluate the re-effects of proposed landfills (El-Naqa 2005; Thomas et al. 2017). Considering the uncertainty in the common EIA methods (Khosravi and Jha-Thakur 2018), Deng et al. (2014) invented the D number approach, modified by Wang and Wei (2018). All these strategies are aimed at mitigating the effects of developmental projects on the population and environment. Numerous EIA studies have also been conducted on several social and economic development projects in Iran using different methods (Momeni et al. 2011; Mirzaei et al. 2012; Khosravi and Jha-Thakur 2018). Despite the different methods and approaches of EIA, researchers and environmentalists continue to encounter new and severe challenges about methods' response to increasing socio-economic development (Momeni et al. 2011; Khosravi and Jha-Thakur 2018).

In the context of Iran, state-owned enterprises dominate the different sectors of the economy with the cement industry as a strategic commodity playing an essential role in promoting the developmental goals of the country. Cement industries in the Ghayen region, for example, account for one of the largest exports. However, the Ghayen region in Birjand is prone to drought and many aqueducts are constructed to provide water to the population coupled with the effects of climate change. The cement production process in Ghayen Cement Factory produces millions of tons of by-products each year including dust, toxic gases, and heavy metals, which pose health and respiratory hazards. The type of energy used in the production process may accelerate pollution (Heidari et al. 2017). This has been further aggravated by increasing greenhouse gas (GHG) concentrations in the atmosphere coupled with rising urbanization contributing to climate change (Sarvari et al. 2019). It should, however, be noted that the production process in cement industries varies from one country to another and from one industry to the other. In the case of Egypt, for example, two different companies use different sources of energy for production purposes; the Egyptian cement plant (ECP) uses electricity, natural gas, diesel, and Mazut and Egyptian hypothetical plant (EHP) use electricity and coal. The Swiss cement plant (SCP) on the other hand depends on electricity, natural gas, and coal (Ali 2014; Ali et al. 2016).

Certainly, the level, intensity, and effects of pollution from these cement factories on the environment and on human health will equally vary. These impurities pollute aqueducts and other water sources resulting in water-related illnesses.

Wastes from the cement industries are indiscriminately disposed causing serious pollution to the environment. It has been reported that the largest contributors to air emissions from gray cement manufacturing, for example, are CO₂, sulfur dioxide (SO₂), oxides of nitrogen (NO_x), and dust/particulate matter (PM) (Brown et al. 2014; Hajiloo et al. 2019; Kadhum 2020). Furthermore, Li et al. (2014) argue that the input data do not only contain traditional items like raw material, energy, and admixtures but also freshwater which unfortunately has not been adequately considered in the literature. However, gray cement facilities, for example, are required to report these emissions for the development of intensity-based environmental performance indicators (Brown et al. 2014). Comprehensive information on the effects of air pollutants on human health is, therefore, essential for the development of efficient policies (WHO 2003; Heidari et al. 2017). However, the privation of flawless policies, strategies, and plans on national land use management patterns have further jeopardized EIA (Mirzaei et al. 2012). This study, therefore, investigates the environmental impacts of the Ghayen Cement Industry on environmental components and public health using a mathematical matrix.

Materials and methods

Study setting

The Khorasan province is located in the northeastern part of Iran with Qaen as the capital also called the city of Saffron. This is because Qaen is the major producer of Saffron in the country.

The Ghayen Cement Complex is located in South Khorasan Province, near the city of Semi-Block between latitude 33° 43' 35.08" and 33° 44' 02.78" north and longitude 59° 00' 10.14" and 59° 11' 38.41" east and at an altitude of 1440 m above the sea level (see Fig. 1), with a total area of 604 ha. It is the most renowned cement industry producing about 2000 tons of assorted cement daily. The license for the construction of this complex was approved with the aim of producing 800,000 tons of assorted light-alloy cement ingot per year. The Qaen cement industry is one of the leading exporters of cement in the east of Iran. The region has a Mediterranean climatic type with annual temperature and rainfall of 12.4 °C and 380 mm, respectively (Khalili et al. 2020). This fluctuates rainfall throughout the year with a cool period stretching over 95 days per year. This limited rainfall coupled with pollution from the cement industry influences the amount and quality of water for domestic use in particular (Khalili

et al. 2020). The increasing contribution of Iran to GHG emissions particularly from the increasing production of fossil fuels and rising urbanization is bound to further increase temperatures while precipitation decreases (Sarvari 2019; Mansouri Daneshvar et al. 2019).

Mathematical matrix research method

Thus, data for the study were obtained through the use of a descriptive-analytical method. This was to evaluate the environmental effects of Ghayen Cement Industry. Noteworthy is that the mathematical matrix research method is appropriate to coordinate and control the functional and project activities. Furthermore, it is adaptable to a dynamic environment. The assessment of the effects of development took several steps to ensure that all predictive effects are taken into account. Salehi et al.'s (2012) three-stage process was used; this includes:

1. Description of the project and environmental characteristics
2. Identification and prediction of the effect
3. Valuation of the significance of the project's description and the characteristics of the environment

The first step is based on the interaction matrix. At this stage, experts and decision-makers defined the project activities and the environmental components that may be affected. These experts separately evaluated the environmental components in the matrix cells. Furthermore, the criteria were defined as the two profiles of interactions and environmental susceptibility (Bojórquez-Tapia et al. 1998; Mussa 2018).

Environmental factors

- i) Air pollution and micro-climate. Identification and prediction of the effects of a cement plant on the region's climate are possible. The effects of certain activities, such as the use of vehicles, the construction of buildings, and the increase of air outflows, can contribute to climate change especially in the micro-climate of the factory site and around it.
- ii) Water pollution: Physical actions such as changes in river flow cause ecological changes. Also, sedimentation and increase of sediment in the river reduce river flow and the depth of the river. This also affects aquatic life, with its cumulative effects.
- iii) Sound pollution: The noise in the construction stages and possibly exploitation will be more than the current level. Linear noise sources can include traffic and vehicle traffic for entering and leaving the area and its perimeter.
- iv) Soil pollution: The presence of contaminants in soil from cement production processes, in high enough concentrations, poses an enormous risk to human health

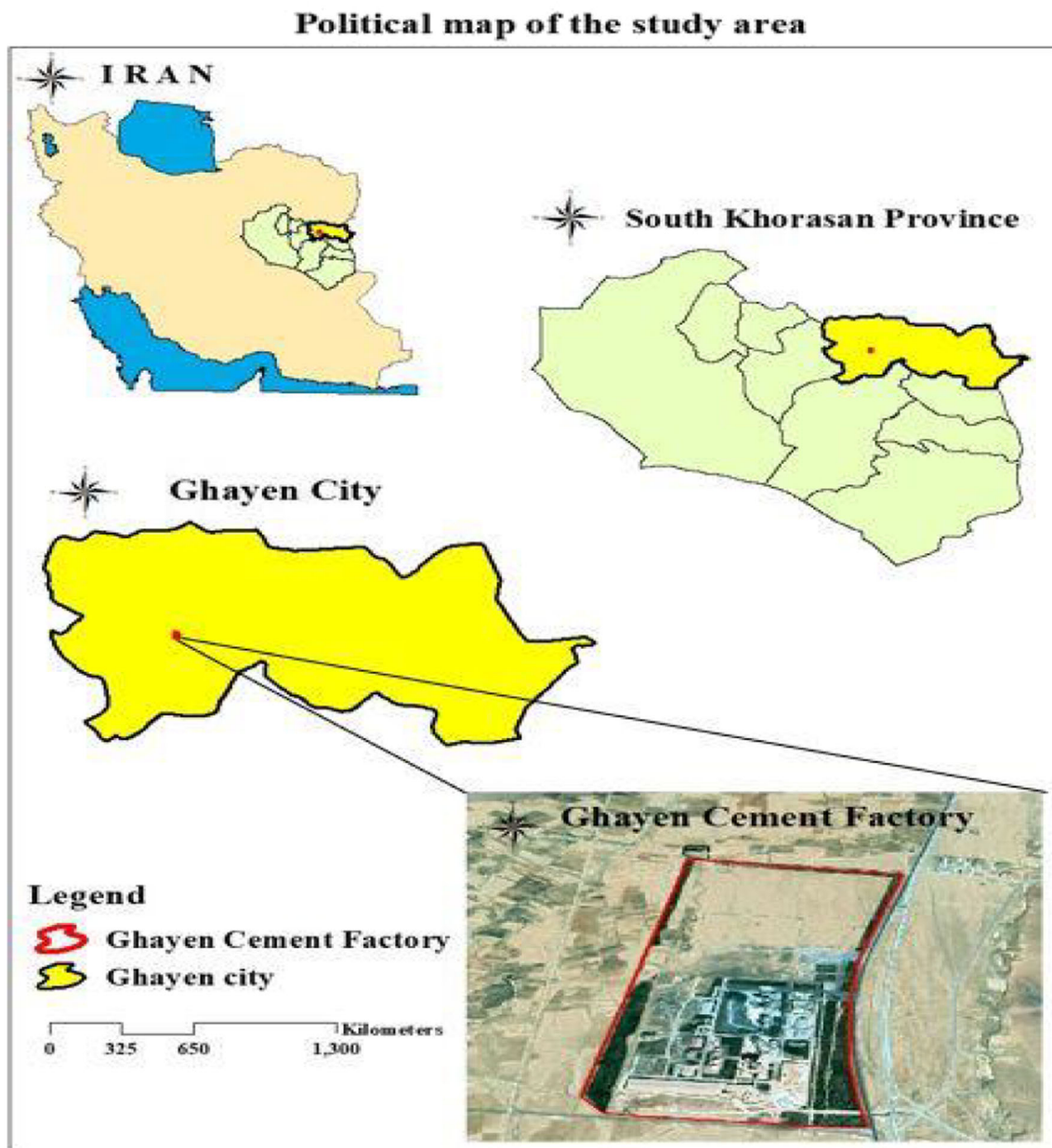


Fig. 1 Map of Iran showing the South Khorasan Province, Ghayen City, and Ghayen Cement Factory. Source: (Authors, 2019)

and/or the ecosystem. Soils can also be polluted by exchanging their properties such as increasing levels of the toxic substances in soil and a change in pH, potassium (K), calcium (Ca), magnesium (Mg), and soil organic matter. Some of the pollutants are industrial waste disposed on the environment. Even when their levels are not high enough to pose a risk, soil pollution is still said to occur if the levels of the contaminants in soil exceed the levels that should naturally be present.

v) Biodiversity: The destruction of the biodiversity was predominance during the construction phase of the industry. The reduction of vegetation modifies habitats and causes changes in human and animal populations.

Animal species are also lost due to the loss of their habitat or the inevitable emergence of new habitats and shelters that can find their ecological conditions.

vi) Socio-economic and cultural environment: Several changes take place during and after the construction phase of projects. These results in various forms of pollution which are likely to adversely affect the population of the region. Such projects equally affect the movement of people and this is susceptible to affect the local economy and culture of the area. Cultural environments can cause serious damage to the project. Also, touristic and recreational centers, ancient monuments, and historical, cultural, and religious monuments are among the first

places where harmful effects from industries are felt (Monavari 2002; Dhoble 2013).

Evaluation and weighting of mathematical matrix criteria

After weighing and valuing each of the main and complementary criteria by experts, the importance of mutual effects was assessed by a series of basic and supplementary indexes. The intensity of interaction between project activities and environmental components was evaluated using seven major criteria: magnitude and duration of effect, more effects, cumulative effects and differences of opinion, as well as the criterion of compensation effect.

Calculation of basic criteria Basic criteria include magnitude, extension, and duration of effect. First, the experts used the matrix base scores for each of the three options and finally applied the researcher's opinion and analyzing expert opinions. The final weight was also applied to the matrices. Basic criteria are essential for defining interactions while the complementary criteria complete the descriptions. However, they do not describe the effects. Scoring is based on a scale from 1 to 9 (Şahin et al. 2019). From these two profiles (base and complementary), the quantitative effect between the two variables i and j can be estimated. The variables i and j represent the environmental components¹ and the activities of the project, respectively.

$$ED_{ij} = \frac{1}{27}(M_{ij} + E_{ij} + D_{ij}) \quad (1)$$

This equation calculates the magnitude of the effects, the extent of the effects, the duration of the effects, the components of the environment, and the activities of the project (Mussa 2018).

Calculation of complementary criteria Complementary criteria include the combined effects of synergy, cumulative effects, and controversy that there is about the effects. Scores are considered for each of the complementary criteria range from 1 to 9.

$$SAC_{ij} = \frac{1}{27}(S_{ij} + A_{ij} + C_{ij}) \quad (2)$$

In this equation S_{ij} indicates more effects; A_{ij} cumulative effects; C_{ij} disagreements; i environmental components; j -project activities (Bojórquez-Tapia et al. 1998; Mussa 2018); and I_{ij} calculation of interactions between project activity and environmental components.

¹ Environmental components in this context refer to all the physical and biotic conditions that surround the organism externally.

After calculating the basic and complementary criteria, the results were included in the findings of Bukhorkoes Tapia et al. (1998) in Eq. (3–3) and their results were used to calculate the significant effects (Da Silva Dias et al. 2019).

Calculation of meaningful effects In this stage, the results of complementary criteria, basal measures, interactions, and compensatory effects were used to calculate meaningful effects according to the studies of Bojórquez-Tapia et al. (1998) in the following equation.

$$\emptyset = 1 - SAC_{ij}^I \quad (3)$$

$$I_{ij} = MED_{ij}^{\emptyset} \quad (4)$$

G_{ij} is the significance level, T_{ij} compensation factor, and I_{ij} effective interaction between project activity and environmental components.

Calculation of compensation profile: this equation is used to obtain meaningful effects.

$$G_{ij} = I_{ij} \left[1 - \left(\frac{T_{ij}}{9} \right) \right] \quad (5)$$

$$F_{ij} = 1 - T_{ij}/9 \quad (6)$$

Finally, we divided the effects into four groups (Bojórquez-Tapia et al. 1998): the little effect (0.0–0.24), moderate effect (0.25–0.49), great effect (0.50–0.74), and high effect (1–0.75) (Salehi et al. 2012). The data were finally analyzed using Microsoft Excel Software based on the above division.

Results

Basic index

Results from the study show that the basic index (magnitude, extent, and duration of effect) have different intensities in the project. For example, the highest destructive effect of excavation and land deformation was 0.67 and the least effect on water pollution 0.11. These are serious threats to public health. The highest degree of leveling effect was achieved on habitat degradation and land deformation was 0.26 and the lowest degree of leveling effect on water pollution was 0.04. Also, the highest and lowest destructive effects of road construction on habitat destruction and public health threat were 0.63 and 0.07, respectively. The highest destructive effect on transportation was on reducing biodiversity and noise pollution (equally), and the lowest effect on water pollution was 0.48 and 0.07, respectively. The highest destructive effect of effluent and waste disposal was on biodiversity reduction and the lowest effect on noise pollution was 0.70 and 0.07, respectively (see Table 1). In terms of basic criteria, the most destructive

Table 1 Results of calculating of basic index (MED)

Activities Parameters	Excavator	Leveling	Road construction	Transportation	Waste and waste disposal
Air pollution and microclimate	0.63	0.19	0.37	0.37	0.19
Water pollution	0.11	0.04	0.15	0.07	0.70
Soil erosion and contamination	0.59	0.37	0.26	0.19	0.41
Noise pollution	0.26	0.37	0.48	0.48	0.07
Ground deformation	0.67	0.30	0.56	0.19	0.33
Habitat destruction	0.41	0.26	0.63	0.19	0.33
Reduce biodiversity	0.33	0.26	0.44	0.48	0.30
Public health	0.11	0.11	0.07	0.19	0.52

impact was related to the effect of wastewater and waste disposal on water pollution amounting to 0.70.

to the environment and public health coupled with the effects of climate change.

Complementary criteria

With respect of the complementary criteria, the study found out that the highest destructive effect of excavation was on habitat destruction (0.41) and the least effect on the threat was on public health, soil erosion, and pollution (0.07). The highest level of leveling was achieved on air/micro-pollution and noise pollution (0.15), while the lowest level of impact on public health threats and habitat destruction was (0.07) (see Table 2). The highest destructive effect of road construction on reducing biodiversity was 0.56; the lowest destructive effect of road construction on noise pollution and deformation of the earth was obtained at 0.77. The highest destructive effect of transportation on air and micro-pollution and noise pollution was 0.15, and the least effect on water pollution, land deformation, and habitat destruction were 0.07. The highest destructive effect of wastewater and waste disposal was on the threat to public health (0.37), and the lowest effect on soil erosion and pollution and noise pollution was 0.77. In terms of complementary criteria, the most destructive effect was related to road construction resulting in the reduction of biodiversity by 0.56. These effects have serious consequences

Calculating the interaction of project activities (basic and complementary criteria) on environmental components

The study revealed that the interaction effect of project activities (basic and complimentary basic criteria) on environmental components had varied stages. For example, the highest destructive effect of excavation was on land deformation (0.70), and the lowest effect was on threats on public health threat (0.13). The highest level of leveling effect on soil erosion and pollution was 0.41, while the lowest level of leveling effect was on water pollution (0.5). The most devastating effect of road construction was on habitat degradation and biodiversity reduction (0.70). Also, the lowest destructive effect of road construction on public health threats was 0.10. In the transport sector, the highest effect was on noise pollution (0.54), and the lowest effect was on water pollution (0.09). In the same vein, the highest destructive effect of wastewater and waste disposal was on water pollution (0.73), while the lowest effect on noise pollution was (0.09) (see Table 3). Regarding the interaction effect of project activities on environmental components, the most destructive effect was related

Table 2 Results of calculation of complementary index (SAC)

Activities Parameters	Excavator	Leveling	Building a way	Transportation	Waste and waste disposal
Air pollution and microclimate	0.15	0.15	0.15	0.15	0.11
Water pollution	0.11	0.11	0.15	0.07	0.11
Soil erosion	0.07	0.11	0.11	0.11	0.07
Noise pollution	0.11	0.15	0.07	0.15	0.07
Ground deformation	0.11	0.11	0.07	0.07	0.11
Habitat destruction	0.41	0.07	0.22	0.07	0.07
Reduce biodiversity	0.11	0.11	0.56	0.11	0.11
Public health	0.07	0.07	0.11	0.11	0.37

Table 3 Results of interaction of project activities (basic and complementary criteria) on environmental components (I_{ij})

Activities Parameters	Excavator	Leveling	Building a way	Transportation	Waste and waste disposal
Air pollution and microclimate	0.67	0.24	0.43	0.43	0.22
Water pollution	0.14	0.05	0.20	0.09	0.73
Soil erosion	0.61	0.41	0.30	0.22	0.44
Noise pollution	0.30	0.35	0.51	0.54	0.09
Ground deformation	0.70	0.30	0.58	0.21	0.38
Habitat destruction	0.58	0.29	0.70	0.21	0.36
Reduce biodiversity	0.38	0.26	0.70	0.52	0.34
Public health	0.13	0.13	0.10	0.22	0.66

to the effect of wastewater and waste disposal on water pollution (0.73). This translates to public health challenges which affect the productivity of the people (Table 4).

Significant calculation of effects by considering the compensation factor

In the mathematical matrix, the compensating factor ($T_{(ij)}$) is used to reduce or eliminate negative effects and increase positive effects. This factor represents the compensatory activity that is being undertaken in the industry to reduce the effects of project activity $T_{(ij)}$. Considering the destructive effects and the consideration of the conditions of each region, they were rated in the interval from 1 to 9 (Salehi et al. 2012). The result of this scoring was laid out in the formula of calculating meaningful effects (Equivalent 5). Multiplying the interaction between project activity and environmental components (I_{ij}) in the compensation index (f_{ij}) gives a significant level (G_{ij}). The results of calculating the effect of project activity on environmental components (I_{ij}) as well as the effect factor compensation were used to achieve significant effects. The meaningful calculation of the effects was carried out using Eq. (5) (see Table 5). Table 5 shows the significant calculation of the effects. The highest significant effect of excavation was on land deformation (0.54), while the least significant effect

was on the threat to public health (0.09). The highest significant degree of leveling on soil erosion and pollution was 0.32. The highest significant effect of road construction on noise pollution and land deformation was 0.45. The lowest significant effect of road construction on the threat of public health was 0.08. Still in the significant calculation, the highest significant effect of transport on noise pollution was 0.48, while the lowest effect on water pollution was 0.08. The highest significant effect of wastewater and waste disposal was (0.41), and the lowest significant effect on noise pollution was 0.08 (Table 5).

Division of significance of effects

Results of meaningful effects showed 4 categories: L, low, M, medium, H, high, and VH, very high. The results of this categorization are presented in Tables 6 and 7. Table 6 shows the partition is without a compensation factor, while Table 7 shows the correction by applying the factor. The results regarding embankment and excavation operations without considering the compensatory factors showed that 2 items of low significance effect were in the area; 2 items of moderate significance effect and 4 items of high significance effect were in the area. Regarding the leveling operation, 3 items of low significance effect and 5 items of moderate significance effect

Table 4 Results of the compensation index (f_{ij})

Activities Parameters	Excavator	Leveling	Building a way	Transportation	Waste and waste disposal
Air pollution and microclimate	0.44	0.44	0.78	0.44	0.44
Water pollution	0.78	0.89	0.78	0.89	0.56
Soil erosion	0.44	0.78	0.78	0.89	0.89
Noise pollution	0.67	0.78	0.89	0.89	0.89
Ground deformation	0.78	0.89	0.78	0.89	0.44
Habitat destruction	0.33	0.67	0.56	0.67	0.56
Reduce biodiversity	0.56	0.67	0.56	0.67	0.78
Public health	0.55	0.55	0.77	0.77	0.33

Table 5 Results of significant calculation of effects (G_{ij})

Activities Parameters	Excavator	Leveling	Building a way	Transportation	Waste and waste disposal
Air pollution and microclimate	0.30	0.11	0.33	0.19	0.10
Water pollution	0.11	0.05	0.15	0.08	0.41
Soil erosion	0.27	0.32	0.23	0.20	0.39
Noise pollution	0.20	0.28	0.45	0.48	0.08
Ground deformation	0.54	0.27	0.45	0.19	0.17
Habitat destruction	0.19	0.19	0.39	0.14	0.20
Reduce biodiversity	0.21	0.18	0.39	0.35	0.26
Public health	0.09	0.07	0.08	0.17	0.22

were in the area. Regarding road construction operations, 2 items of low significance effect, 2 items of moderate significance effect, and 4 items of high significance effect were in the area. In terms of transportation operations, 5 items of low significance effect, 1 item of moderate significance effect, and 2 items of high significance effect were in the area. Concerning waste disposal and effluent operations, 2 items of low significance effect, 4 items of moderate significance effect, and 2 items of high significance effect were in the area (see Table 6). The results showed that the compensation factors of 35%, 35%, and 30% of items (out of the 40 items) are of low, medium, and high effect, respectively (see Table 6).

Results regarding embankment and excavation operations, the compensatory factors showed that 5 items were in the area of low significance effect, 2 items were in the area of moderate significance effect, and 1 item was in the area of high significance effect. In terms of leveling operations, 5 items of low significance effect and 3 items were of moderate significance effect. Regarding road construction operations, 3 items were of low significance effect and 5 items were of moderate significance effect. On the subject of transportation operations, 6 items were of low significance effect, and 2 items were of moderate significance effect in the area. Concerning waste disposal and effluent operations, 5 items were in the low significant effect area and 3 items were in the medium significant effect area (Table 7). The results showed that considering the 60%, 37%, and 3% compensation factors, the items (out of the 40 items) were in the low effect area, medium effect, and high effect, respectively (see Table 7). Therefore, the use of

compensation factors reduced the harmful effects of projects on the environment.

Table 6 shows the environmental effects of project implementation without the use of compensatory factors as opposed to Table 7 showing the effect of the application of compensatory factors on reducing the destructive environmental effects of projects.

Discussion

Economic growth and development have adversely affected our natural environment. This is because inadequate attention has been given to the environmental issue and this has resulted in the increasing realization of the significance of tackling environmental concerns early in project planning (Dhoble 2013). Results from the study showed that the highest destructive effect of excavation and land deformation was 0.67 and the least effect on water pollution 0.11. The excavation of the substrate materials creates excavation voids which modify the topography, hydrology, soil profile, and the nutrient status of the substrate. The resultant features have potentially harmful effects on the local biodiversity and a serious threat to public health. In the case of Iran with one of the biggest cement factories in the world, the effects of air pollution, for example, are manifested as dust generation and subsequent increase in suspended particulate matter (SPM) in the environment (Dhoble 2013; Hajiloo et al. 2019). Another important aspect of these cement factories is the energy-intensive nature with

Table 6 Results of the classification without the effect of compensating factor

Division of effects	Embankment and excavator	Leveling and squaring	Construction of the main and secondary routes	Transportation of materials	Disposal of waste and waste	Total effects	
L	0–0.24	2	3	2	5	2	14
M	0.25–0.49	2	5	2	1	4	14
H	0.50–0.74	4	0	4	2	2	12
VH	0.75–1	0	0	0	0	0	0

Table 7 Results of the classification with the effect of compensating factor

Division of effects		Embankment and excavator	Leveling and squaring	Construction of the main and secondary routes	Transportation of materials	Disposal of waste and waste	Total effects
L	0–0.24	5	5	3	6	5	24
M	0.25–0.49	2	3	5	2	3	15
H	0.50–0.74	1	0	0	0	0	1
VH	0.75–1	0	0	0	0	0	0

high levels of pollution which is not only a threat to humans but to the ecosystem. Interestingly, studies have been conducted to investigate energy reduction possibilities (Brown et al. 2014). For example, reduction in CO₂ intensity for cement is attributed to the increased usage of ground limestone to lower the clinker content in cement, increased usage of renewable fuels which supplant fossil-based fuels, and incorporating supplemental cementitious materials (Brown et al. 2014).

Similarly, Josie et al. (2012) highlight the gravity of ecological effects on the human population. The most serious environmental conflicts in the cement industry revolve around access to limestone reserves in protected areas with biodiversity richness and areas of special cultural significance (Dhoble 2013). Life cycle assessment (LCA) studies have, however, been introduced on how to mitigate the emissions of greenhouse gases from the cement industry (Ali et al. 2016). Unfortunately, most output data contain not only greenhouse gases and primary pollution (SO₂, NO_x, and PM) but also the hazardous air pollutants (PCDD/Fs, NMVOC, HCl, PAHs, and fluoride) along with noise and heavy metal emissions (As, Cd, Cr, Hg, Ni, Pb, Zn, Cu) which are usually neglected by others (Li et al. 2014; Kadhum 2020). Since Iran is a predominantly desert country, the impact of limestone extraction is intensified by noise and visual intrusion arising from both mining and secondary activities, including transportation (Dhoble 2013; Sarvari 2019). National governments have, therefore, been encouraged to craft environmental policies to regulate emissions from cement factories to improve their ambient air quality (Brown et al. 2014). This is the case in India, for example, where environmental impact assessment (EIA) has been introduced with supporting legislative and institutional framework to regulate the production, emission, and disposal of industrial wastes (Ritu 2006). It is unfortunate that some of these policies and planning strategies hinder proper EIA (Mirzaei et al. 2012).

With respect of the complementary criteria, the study revealed that the highest destructive effect of excavation was on habitat destruction (0.41), and the least destructive effect of the threat was on public health, soil erosion, and pollution (0.07). It is clear in the study, and in line with the work of Dhoble (2013), that environmental impacts occur generally in the form of alteration of landform features and fragmentation of biological habitats. The alteration of landforms can possibly result in altered patterns of stream flows and drainage pattern. The study further

demonstrates that the highest level of levelling was achieved on air/micro-pollution and noise pollution (0.15) while the lowest level of impact on public health threats and habitat destruction was 0.07. Importantly, cement manufacturing contributes towards air pollution through the addition of gaseous pollutants to the atmosphere and the increase in a load of suspended particulates. Among the effects on the physical environment, the most adverse effects are on air quality. This contradicts the study of Kiani et al. (2015) which argued that the most harmful effects on the environment are the destruction of agricultural lands and pollution of soil resources. However, several authors have highlighted the adverse environmental effects of aqueous cement plant (Karbasi et al. 2013; Kiani et al. 2015). The adverse effects of cement factories, for example, are mostly related to the production of sulfur dioxide (SO₂) which is explicitly confirmed by the Central Pollution Control Board regulations (CPCB 2010). Meanwhile, SO₂ pollutes the air quality and endangers the ecosystem and human health (Mittal et al. 2014; Wang et al. 2015). Indeed, air pollution by SO₂ affects negatively on human beings in terms of corneal haze, breathing difficulty, airways inflammation, eye irritation, psychic alterations, pulmonary edema, heart failure, and circulatory collapse (WHO 2003; EPA 2011; Wang et al. 2015). Studies have also highlighted the importance of reporting air emissions such as CO₂, SO₂, NO_x, and PM in cement facilities to assist in the development of intensity-based environmental performance indicators (Brown et al. 2014; Sarvari 2019). It is unfortunate that national governments and industries fail to take seriously the effects of socio-economic impacts of environmental activities and the right of those affected to be part of the assessment and decision-making processes (Lockie et al. 2008). In this context, Khosravi et al. (2019) argued that the development of public participation in EIA legislation is influenced by the political system of a country. As such, public participation is overlooked in countries where the political system is rigid and less democratic. However, other studies have documented that public participation is crucial in the success of developmental projects (Pagatpatan et al. 2018; Tantoh and Simatele 2018; Hasan et al. 2018; Khosravi et al. 2019).

The study also reveals that meaningful effects showed 4 categories: L, low, M, medium, H, high, VH, very high. The results of this categorization are without a compensation factor. This complements the study of Kiani et al. (2015) and further highlighted the most harmful effects on the

environment. However, environmental assessment has been shown to be an effective tool in providing short- and long-term planning for the provision of appropriate and logical ways of using human and natural resources. Knowledge of the community as a whole increases as the environmental assessment relates to the planning process. In addition, when those mostly affected by the impacts of a project are involved in the different stages of EIA and decision-making processes, the chances of the success of the project increase (Lokie et al. 2008; Tantoh and Simatele 2018). This equally aligns with the findings of Rolfe et al. (2005) who noted that public participation in socio-economic impact assessment increases awareness and understanding. This will also prevent irreparable effects on the environment and natural resources (Mittal et al. 2014; Ali et al. 2016).

Conclusion

Environmental impact assessment is an indispensable tool for proper implementation of major projects. However, thematic records show that environmental considerations have been seldom considered in industrial projects in Iran and the consequences of such actions include various pollution and severe destruction and depletion of environmental resources. This study examined the environmental impacts of the Ghayen Cement Industry on environmental components and public health using a mathematical matrix. The results revealed that the effect of the cement factory on the environment produced four categories significant effects: L, low; M, medium; H, high; and VH, very High with adverse effects on human health and the environment. Pollution from cement factories can have irreparable effects on the environment and public health if adequate environmental impact assessment is not conducted and implemented. The type of energy used in the production process equally aggravates pollution. Thus, developers should provide methods to eliminate, reduce, or control possible adverse environmental effects and provide the possibility of renewal, restoration, and compensation of damage to the environment. The study argues that the use of common methods of environmental improvement such as erosion control, proper location of facilities, and the creation of green spaces is essential to mitigate the impacts of projects on the environment. Further research is required to establish an inclusive EIA performance in Iran to explore advance methods and factors that influence EIA implementation and performance. This will oblige industries to take all the mitigation measures into consideration in an eco-friendly style and with an undertaking that they would effectively follow all the norms prescribed by the State from the time to time.

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Authors' contributions J. D: conceptualized and wrote the original draft. S. B.: supervision and critical review of the manuscript. H. B. T: Writing, visualization, preparation, editing, and finalization.

Data availability All data generated and analyzed during this study are available on reasonable request.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Ethical approval Approval was obtained from the ethics committee of the University of Birjand. The procedures used in this study adhere to the tenets of the Declaration of Birjand.

Consent to participate Not applicable.

Consent to publish Not applicable.

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