## Vision 2040 for Greater Khartoum Sustainable City

The first approach for environmental sustainable development to the global community was introduced in 1992 in the United Nations conference on environment and development, the "Earth Summit", that took place in Rio de Janeiro, Brazil. Defining sustainable development as the one that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Therefore, the study will focus on the United Nations Sustainable Development Goals UN-SDGs and the making of sustainable cities. The aim of the research is to propose a framework to transform Greater Khartoum into a sustainable city and to find out criteria for an assessment method that is applicable for Greater Khartoum, which includes: providing safe affordable housing and basic services, sustainable transportation, sustainable home settlements in the three towns, protect culture and natural heritage, reduce waste including water, air and solid waste, public access, green-space, support positive economic, social and environmental links between urban and rural areas, national and local disaster risk reduction strategies, inter-linkages and implications for policy-making.

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Khogali Osman

Scholars' Press

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Eco City - Eco Neighborhood - Eco Buildings

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**Imprint**



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# DEDICATION

In His Holy Book, the Almighty Allah mentioned: "And says (unto Act! Allah will behold your actions, and (so will) His messenger and the believers, and you will be brought back to the Knower of the Invisible and the Visible, and He will tell you what you used to do" (Surat Al-Tawbah. 105); and He mentioned: "And We have enjoined Upon man concerning his parents - His mother beareth him in weakness Upon weakness, and his weaning is in two years - give thanks unto Me and unto thy parents. Unto Me is the journeying" (Surat Luqman, 14). This dissertation is dedicated to my beloved mother Mrs. Al-Sareerah Mohammad Ata-Almanan. I cannot find more eloquent words than Prophet Mohmmad's words Peace Be Upon him as he mentioned: "Who is the worthiest of your company? He mentioned: Your mother. Then, he added: Your mother and added: Your mother, then, your father". My dear father, Engineer Dr. Abdel Moneim Khogali, who worked and struggled until his name flew up in the sky of Sudan. His plant has produced delicious fruits literally speaking. I pray Almighty Allah to watch over him, protect him, and bestow upon him His blessings and bounties. It is a great honour and source of ultimate happiness to me to dedicate this effort and dissertation to my beloved parents, in recognition of their love and care. I also dedicate this effort and dissertation to my respectable beloved husband, Dr. Al-Fatih Mohi Al Dein. I cannot forget, and I appreciate your endless and relentless support and love. I also dedicate this work and dissertation to my beloved children: Muhammad, Momen, Mazin and Noon. This work should be a guiding light for you to follow on the path of knowledge and learning.

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# CHAPTER ONE

# SUSTAINABLE ECO-CITY

# Assessment method on united nation sustainable development goals, applied for a sustainable city, with a focus on Greater Khartoum services

## 1.1. Abstract

The first approach for environmentally sustainable development to the global community was introduced in 1992 in the United Nations conference on environment and development, the "Earth Summit", which took place in Rio de Janeiro, Brazil. (genda21). Defining Sustainable development as the one that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

Therefore, the study will focus on the United Nations Sustainable Development Goals UN-SDGs and the making of Sustainable cities. The aim of the research is to propose a framework to transform Greater Khartoum into a Sustainable city and to find out criteria for an Assessment Method that is applicable for Greater Khartoum. Which including: providing Safe affordable housing and basic services, Sustainable transportation, Sustainable home settlements in the three towns, Protect culture and Natural Heritage, Reduce Waste including water, air and solid waste, Public access, Green-space, Support positive economic, social and environmental links between urban and rural areas, National and local disaster risk reduction strategies, Interlinkages and implications for policy-making.

In addition, the methodology of the research focuses on defining, identifying and measuring the indicators and sub-items. The measurement applied through survey and questionnaire. Distributed and distribute to all engineers specialized in architecture, urban, civil, electrical and mechanical engineers in the three cities (Khartoum-Khartoum North-Omdurman).

Finally, the outcomes of the research, applying the criteria of SDGs to evaluate the present situation in sustainable development criteria in Greater Khartoum; most of the indicator record results The research recorded results show that the goals were not achieved in most of the situations, between (20-30) especially in services (Table 1), waste

management and open spaces are average (40-49). Will provide valuable recommendations towards improving the future and urban planning and sustainable development for the Capital city.

*Keywords*: Sustainable Development Goals, Greater Khartoum Sustainable City, measuring performance indicators (KPI) for Greater Khartoum

## 1.2. Introduction

Greater Khartoum as a city consists of three towns (Khartoum, Omdurman and Khartoum North); it is suffering from many environmental problems like waste disposal, increase of CO2 emission from cars and industrial areas, water waste. The increase in migration towards Khartoum city in the last 20th years; these caused problems in services such as education, affordable houses for those people, hospitals, the basic life needs in goods, homes. Hamid (2010) and HABITAT, (2009).

This research is aiming to find sustainable city indicators according to SDGs11 sustainable development goals No.11 for UN. To be applied in Greater Khartoum. The project consists of two phases; phase one is finding out the indicators for the assessment of the sustainable city in a general framework. Phase 2 is applying the indicators on Khartoum city to find key performance indicator (KPI) measurement and percentage for each criterion.

## 1.3. Literature review

United Nations set up sustainable Development Goals in UN, (1992) in the United Nations conference on environment and development, the "Earth Summit", which took place in Rio de Janeiro, Brazil (genda21), Fox (2000).

UN SDGs (UN, 2018) published criteria indicators (1) Safe affordable housing and (2) basic services, (3) Sustainable transportation, (4) Sustainable home settlements in the three towns, (5) Protect culture and Natural Heritage. (6) Reduce Waste including water, air, and solid waste, Reduce water waste, air and solid waste, (7) Public access, Green- space. (8) Support positive economic, social and environmental links between urban, and rural areas, (9) National and local disaster reduction strategies, (10) Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials, (11) Interlinkages and implications for policy-making. Anderson, (2011) Studied measuring cities indicators for Sweden city focuses on the focus in vision, Indicator framework, indicator selection, stockholder's participation, communication strategy visual design, the study ended by cases study. Commission, (2018) Discussed China Sustainable Index which consists of some indicators like basic needs, Recourses Efficiency, Environment Clean Lines, Built Environment, and Commandment to the environment. The Commission, (2018) Discussed the European tools for sustainable cities such as, change climate mitigation, sustainable urban mobility, sustainable land use, nature and biodiversity, air quality, noise, waste, water, energy, green growth and eco-innovation, energy performance, and governance. KAUST, (2013) presented proposal green building for certificate system for the KSA the development site, transport, atmosphere, indoor air quality, using environmental quality, water, energy, material, eco-innovation, culture, and labour. Ministry, (2018) discussed the parameters of Saudi Arabia smart city the indicators are smart buildings, mobility, security for citizens, healthcare, energy, digitization. Abdelmoneim, H., (2017) a presented paper about categories for the sustainable neighborhood the indicators are sustainable site, neighborhood design, pattern and construction, material and resources, water, Energy, environmental design process and emission and safety. Abdelmoneim, H., (2005) discussed the renewable energy resources in Greater Khartoum which including solar energy and wind energy.

UN-HABITAT, (2015) Published a report about Saudi Future Cities and announced the program (FSCP) the focus indicators are the program studied several cities in Saudi Arabia including Makkah city. UN-HABITAT, (2016) Published a report about Saudi Future Cities and announced the program (FSCP) in Al Medina, UN-HABITAT, (2017) Published a report about Saudi Future Cities and announced the program (FSCP) in Judah city.

HABITAT, (2018) Published a report about Saudi Future Cities and announced the program (FSCP) in Al Riyadh city, the main indicators are urban government and legislation, productivity, infrastructure productivity, quality of life, equity and social. Environmental and sustainability. UN, (2018) and Forum, H. L. P., (2018) discussed and published UNSDGs.

## 1.4. The methodology

The research is based on UN SDGs for sustainable cities. Therefore, the methodology first starts by define, identify then measure the indicator which are safe affordable housing and basic services, sustainable transportation, sustainable home settlements in the three towns, protect the culture and Natural Heritage. Reduce waste including water, air and solid waste, public access, green space, support positive economic, social and environmental links between urban and rural areas. National and local disaster risk, reduction strategies, Interlinkages and implications for policy-making. Consequently, after a comprehensive literature review in urban indicators applying in Europe, Asia and on the region, the researcher applies the survey and questionnaire through Google survey in the social media, focus on engineering groups. The results were analyzed in tables and figures. Finally, the results were discussed for the conclusion.


**Figure 1.1: UNSDGs, The research focuses on goals No.11, sustainable cities**

### 1.4.1. Define the indicator

Commission, (2018) define the indicator as "Indicator: a parameter, or a value derived from parameters, which points to, provides information about, and/or describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value".

### 1.4.2. How to identify the indicators

1. The indicator should be remarkable
2. In addition, it could be measured as a percentage
3. Consequently, the measures could be updated
4. Furthermore, it required good data based on monitoring


**Figure 1.2: Shows the three main components of sustainable development, source: Commission, (2018)**

### 1.4.3. How to measurement the indicators

The indicator could be measured by survey and Questionnaire. The researcher applies the survey and questionnaire through a Google survey in the social media, focus on engineering groups. The results were analyzed in tables and figures

**Table 1.1: The evaluation scale**

| The evaluation | The evaluation scale | The meaning of the evaluation |
|---|---|---|
| Very strong factor | (70-80) | Achieve the goals<br>There is policy, plan, apply, measured, with benchmarking and recycling |

| | | |
|---|---|---|
| | | the process after 5 years |
| Strong Factor | (60-69) | Achieve the goals<br>There is policy, plan, apply, measured, with benchmarking |
| Moderate | (50-59) | Achieved the goals<br>There is policy, plan, apply, measured |
| Weak | (40-49) | Not achieve the goals |
| Very Weak | (0-39) | Not achieve the goals |

### 1.4.4. The survey and questionnaire

The survey distributed by Google forms through many engineering groups in social media, Architects, urban Eng., surveys Eng., mechanical Engineer, civil and Electrical Engineer. The number of responses is 100.

**Figure 1.3: Google Seattleite image, Greater Khartoum including the three towns (Khartoum, Khartoum North, and Omdurman. The circle shows the limit of the study. Khogali, H., (2019)**

## 1.5. The results

The results are shown in the following figures from Fig. 4 to Fig. 17. In addition, Table 1 shows the average result for each indicator and table 2 showed the checklist results evaluation for each indicator the average result is recorded as safe affordable houses (20%), clean energy (16%), clean water (19%), good health (22.6%), good education (17%), and transportation (15%), reduce waste (40%), sustainable home settlement (15%), public access to green space (30%), disaster reduction and strategies (29%), support least development strategies (29%), support positive economics (30%) and interlink to policy making (21%), all the results were below the average and not achieved the goals.

The results are shown in the following.


Figure 1.4: Shows the Affordable housing results

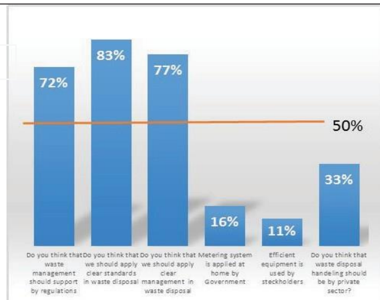


Figure 1.5: Shows the Services: Water efficiency results

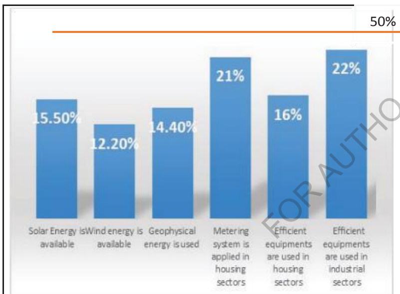


Figure 1.6: Shows the results of clean energy

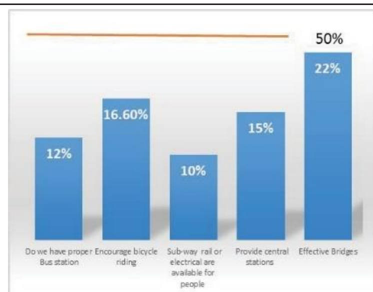


Figure 1.7: Sustainable Transportation results

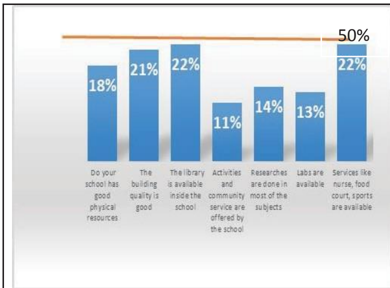


Figure 1.8 Shows education efficiency results

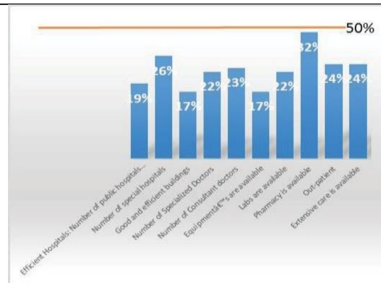


Figure 1.9: Shows Hospitals efficiency results

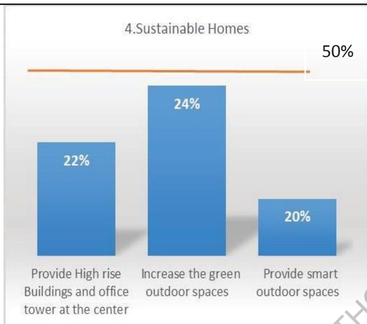


Figure 1.10: Shows Sustainable homes results

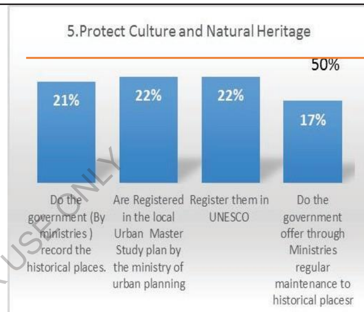


Figure 1.11: Shows protect the culture and natural heritage results

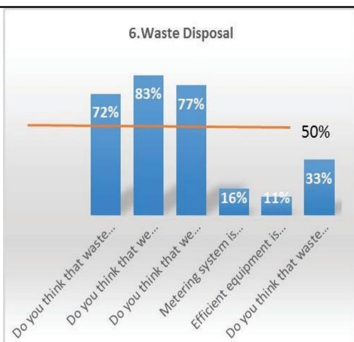


Figure 1. 12: Shows waste disposal results

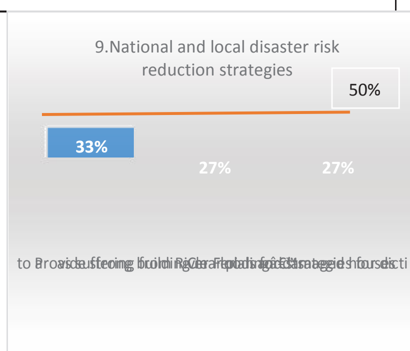


Figure 1.15: Shows national and local disaster risk Reduction strategies

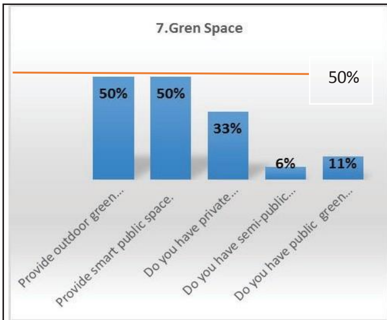


Figure 1.13 Shows Green space results

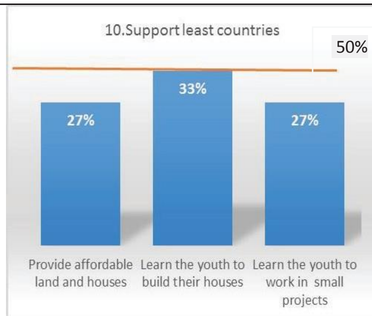


Figure 1.16: Shows the results of supporting the least countries

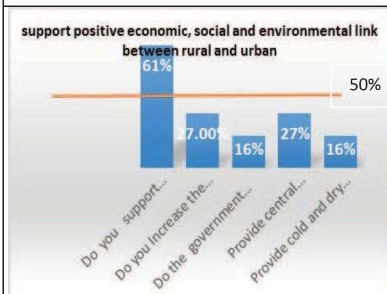


Figure 1.14: Shows support positive economic, social and environmental links between urban and rural areas

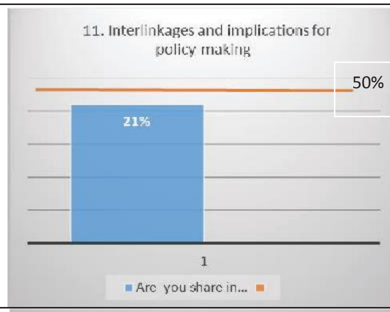


Figure 1.17: Shows the results of interlinks and implications for policymaking

## 1.6. Discussion

The Discussion shows in depth all the points here related to SDG's, the study focuses on Goal no 11' Make cities inclusive, safe, resilient and sustainable.

### 1.6.1. Safe affordable housing and basic services

Greater Khartoum affordable houses are (80%) and 20% lived in illegal houses.

The average result of the survey is shown in table 1, 20% which is evaluated according to the scale as weak.

*The results of the survey were shown in fig. 4 as follows:*

- Does the government apply for global building standards (15%) and apply of local sustainable building standards (20%), the stockholder's (22%) builds healthy houses, and the government (16.6%) and use of local building materials (27.7%) provide affordable houses.

- The Challenges is providing sustainable affordable houses, the use of local building materials and the researcher.
- Note that all the result for this indicator is below the average (20%) and the indicator has not achieved the goals. The priority for improvement is applying of global and local sustainable buildings standards.

### 1.6.2. The services

#### *1.6.2.1. The drainage system infrastructure*

The drainage net in Khartoum 2 since The Colonial period. Other places used well and septic tank by 70%, Gravel and Sand for illegal areas by 20%, which contaminate the underground water (Yassin, 2013).

The average result for clean water is shown in table 1, which is 19.3, which is evaluated according to the scale as very weak.

*The result of the survey in water efficiency shown in fig. 5 as follows:*

- Efficient potable water for drinking is used and available (25%), a water-metering system is applied (21%), do you use grey water recycling (12%).
- The challenges are increasing quality according to the World Health Organization (WHO) standards. Enhance monitoring for the current situation.
- Identifying its impact on Human Health and encourage people to follow orientations.
- The average result for the clean water indicator is (19.2%), the result of the indicator is below the average, and the indicator has not achieved the goals. The priority for improvement is applying the WHO standards for potable water.

#### *1.6.2.2. Clean energy*

The results were shown in fig. 9 solar energy is available (15.5%), wind energy is available (12.2%), geophysical energy is used (14.4%), metering system is applied in the housing sector (21%), and efficient equipment is used in the housing sectors (16%) efficiency is used in the industrial sector in operation (22%).

The challenges are applying renewable energy like solar energy and wind energy and others in Greater Khartoum.

The solutions for the future could be applying more projects using solar energy and wind energy; the government could help in establishing solar plant by sharing with investors in this field.

The average result for clean energy is (16.8%), the result of the indicator is below the average, and the indicator is not achieved the goals. The priority for improvement is applying energy efficiency plans and policies including solar energy system for housing and industrial sectors by the government and the stockholders.

#### *1.6.2.3. Efficient education*

*The results for education efficiency shown in fig. 7 are as follows:*

- The results of quality education were shown in figure 6: Do your school has good physical resources (18%), and the building quality is good (21%), the library is available inside the school (22%), activities and community service are offered by the school (11%). The researchers are done in most of the subjects (14%), are the labs are available (13%) and the services as a nurse, food-court, and sports are available (22%).
- The result for the indicator is below the average (17%) and the indicator has not achieved the goals. The priority for improvement is applying a better education, improvement the buildings quality, providing libraries with good numbers of books, eBooks, digital libraries, encourage the students for reading and writing researches, good activities such as sports and community participation.

#### *1.6.2.4. Efficient hospitals*

*The result of efficient hospitals shown in fig. 8 as follows:*

- Do the government offer efficient hospitals (19%), number of special hospitals (26%), good and efficient buildings (17%), number of specialized doctors (22%), number of consultant doctors ( 23%), equipment are available (17%), labs are available (22%), pharmacy is available (32%), outpatient (24%) and extensive care (24%).

- The challenges are establishing green and sustainable hospitals, providing efficient equipment and supportive treatment for all people.
- The result for efficient hospitals is below the average (22.6%) and the indicator not achieved the goals. Good solutions for the future are built up efficient hospitals by supporting and help of investors.

### 1.6.3. Sustainable transportation

In the three towns (Khartoum, Omdurman, and Khartoum North), there are main transportation bus-stations was built out of the centre to reduce the disadvantages of heavy traffic. There are new bridges like Tuti Island and Almak Nimer new bridges constructed on 2008 and 2009 consequently. (UN-HABITAT, 2016).

*The result according to the survey shown in fig. 9 as follows:*

- Do we have proper bus station (12%), and encourage bicycle riding (16.6%), the subway is available (10%), provide central station (15%) and effective bridges (22%).
- The challenges are constructing of new roads especially ring road, subway around the three towns and more new bridges.
- The result for the indicator is 15%, the result of the indicator is below the average, and the indicator has not achieved the goals. The priority for improvement is applying efficient bus station, subway, central bus station, efficient bridges and ring roads.

### 1.6.4. The sustainable homes settlements in the three towns

Reduce the physical expansion over the agriculture lands; urban sprawl is increasing in Greater Khartoum.

*The results from the survey are shown in fig. 10 as follows:*

- Provide high-rise buildings and office tower at the centre (22%), increase the green outdoor spaces (24%), provide smart outdoor space (20%).
- Challenges are increasing the high-rise buildings, improve the outdoor environment in a landscape, apply to smart outdoor gardens and parks, and improve the transportation system. Establishing of new sustainable urban community and housing. Using proxy indicators.

- The result for the indicator is 22%, the result is below the average and the indicator has not achieved the goals. The priority for improvement is applying high-rise buildings and providing green space at the centre of Greater Khartoum.

### 1.6.5. Protect culture and Natural Heritage

The local building regulations for the National Capital of the Republic of Sudan, and the environmental framework Planning, (2014) by The Ministry of Housing in Khartoum stated the primary setting taking into account historical places and buildings preservation like Khartoum University buildings, Abdel Ghaume Gate, Al Mahdi old Palace, some of Churches In Khartoum.

*The results from the survey are shown in fig. 11 as follows:*

- Do the government record the historical places (by the ministries) (21%), are registered in the local urban master plan (22%), register them in UNESCO (22%) and offers regular maintenance (17%).
- Challenges are Identify the historical places and register them in UNESCO Global Historical places. Many historical places in Greater Khartoum were found since the colonial period and Othman Architecture.
- The result for the indicator is 20.5%, the result is below the average and the indicator has not achieved the goals. The priority for improvement is registering the historical places in UNESCO offers regular maintenance and re-use.

### 1.6.6. Reduce Waste

The waste is including water, air and solid waste: Greater Khartoum is suffering from solid waste, gaseous and water waste.

The average result is 48%, which is evaluated according to the scale as average.

*The results from the survey are shown in fig. 12 as follows:*

- Do you think that waste management should support by regulations (72%), Do you think that we should apply clear standards in waste disposal (83%), Do you think that we should apply clear management (77%), meeting system is applied (16%), efficient equipment is used by stockholder's (11%), and do you think that waste disposal handling should be by private sector(33%).

- Challenges: Government and NGOs should set up regulations and management solutions for private and industrial sectors in order to minimize the solid, gaseous and water waste. Increase quality according to WHO standards. Enhance monitoring for the current situation. Identify its impact on Human Health and encourage people to follow orientations.
- The result for the indicator is 40%, the result is within the average, and the result has achieved the indicator. Priority for improvement is setting up regulations for waste management and monitoring.

### 1.6.7. Public access

Public space is improved, and the government removes Khartoum Hospital to the suburb area. As well as the International Khartoum airport will be removed to the suburb area in Omdurman and reuse its place of public green space.

*The result from the survey is shown in fig 13 as follows:*

- Provide outdoor green space (50%), provide smart public space (50%), do you have a private garden in your home (33%), do you have a semi-public green area at the centre of your neighborhood (6%) and at the centre of your city (11%).
- The average result is (30%) the result is weak.
- Challenges: Transportation efficiency, as well as the, improve road structure, and its drainage net, provide more of public space improvement, more land allocated and reuse these areas for recreations. Provide safety urban space especially for children and women.
- The result for indicator public space is 30%, the result is below the average, and the indicator not achieved the goals. The priority for improvement is applying the public space in all urban levels especially at the middle of the neighborhood and at the centre of the three towns.

### 1.6.8. Support positive economic, social and environmental links between urban and rural areas

To provide a global overview of the state of urban policy at the national level and serves the purpose of monitoring this indicator through four categories: Feasibility, Diagnosis, Formulation, and Monitoring and Evaluation (SDGs). Greater Khartoum has a strong relationship with the suburb areas, especially in the agriculture industry, Cattles and animals' industry. The Government between Greater Khartoum and the rural areas established fast roads.

*The results from the survey are shown in fig 14 as follows:*

- The questions of the survey and the results: Do you support positive economic, social and environmental links between urban and rural areas (61%), do you increase the industry in the rural areas (27%), does the government provide fast and efficient roads (16%), provide central markets (27%), provide cold and dry store (16%). The average result is (29.5%), the result is weak.
- Challenges are providing fast and proper transportation system between the Greater Khartoum and the rural areas, provide central market to welcome these products with cold and dry warehouses, control the prices of these products, regular maintenance of these roads, and support the industry in the rural areas.
- The result for the indicator is 30%, the result is below the average and the indicator not achieved the goals. The priority for improvement is supporting the industries in rural areas, providing fast roads and central markets with all the facilities could help in a successful process.

### 1.6.9. National and local disaster reduction strategies

Supporting sustainable and resilient cities and human settlements and the achievement of the SDGs requires that disaster risk reduction integrated into core social, economic and development planning (SDGs). Greater Khartoum suffering from flooding, Abdulla (2008) stated in his M.Sc. research that Sudan suffered the most destructive floods during the last 20 years. Many cities, especially Khartoum (the capital of Sudan). In addition, the minor earthquake happened in 1946, 1988, 1993, 2010 and 2013 between 3 to 5 Richter. Without any serious effect.

*The results from the survey are shown in fig 15 as follows:*

- Provide protection to the area suffering from river Nile (33%); provide strong building materials for damaged houses (27%), a clear plan and strategies for diction making (27%).
- Challenges are applying the polices to protect the areas suffering from flooding the River Nile.

- The result for the indicator is 29%, the result is below the average and the indicator has not achieved the goals. The priority for improvement is applying strategies for protecting the areas suffering from flooding the River Nile.

### 1.6.10. Support the least development countries

Including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials. The construction industry has a significant impact on material extraction, consumption of natural resources and human comfort (SDGs). Greater Khartoum attracting people from South Sudan, Ethiopia, Eritrea, and from East and West Sudan. The migration reaches 20% of the total Khartoum Population Most of them lived in illegal houses. The Ministry of Urban Planning with UN-HABITAT program me to have a good on-going plan to own these lands and provide services for water and energy.

*The result from the survey is shown in fig 16 as follows:*

- Provide affordable land and houses (27%), learn the youth to build their houses (33%) and learn the youth to work in small projects (27%).
- The average result is 29% and it is weak Challenges are providing safe, low-cost houses, provides services like energy and water, waste disposal to those people. Incur rage people for jobs; construct their houses by bricks and stones.
- The result for the indicator is 29%; the result is below the average; the result not achieved the goals. The priority for improvements is providing affordable land, learn the youth to build their houses and allocate the land for them.

### 1.6.11. Interlinkages and implications for policy-making

Connect the SDGs to urban policies and a clear impact on cities and human settlements. Challenges: update and link the local building regulations for the National Capital of the Republic of Sudan, and the environmental framework (Planning, 2014) by The Ministry of Housing in Khartoum.

*The result from the survey is shown in fig. 17* is (21%), the result of the indicator is below the average, and the indicator not achieved the goals.

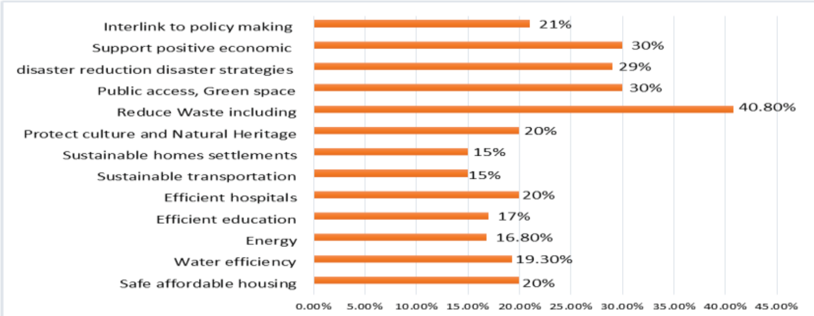


**Figure 1.18: The evaluation for all indicators and the average result**

**Table 1.2: The Evaluation of the results for each indicator.**

| No of indicator | The indicator | The percentage | The evaluation | The result |
|---|---|---|---|---|
| 1 | Safe affordable housing | 20% | Weak | Not achieved the goals |
| 2 | Services | | | |
| 2.1 | Water efficiency | 19.3% | Weak | Not achieved the goals |
| 2.2 | Energy | 16.8% | Weak | Not achieved the goals |
| 2.3 | Efficient education | 17% | Weak | Not achieved the goals |
| 2..4 | Efficient hospitals | 20% | Weak | Not achieved the goals |
| 3 | Sustainable transportation | 15% | Very Weak | Not achieved the goals |
| 4 | Sustainable homes settlements | 15% | Very Weak | Not achieved the goals |
| 5 | Protect culture and Natural Heritage | 20% | Very Weak | Not achieved the goals |
| 6 | Reduce Waste including water, air and solid waste | 40.8% | Average | Not achieved the goals |
| 7 | Public access, Green space | 30 % | Weak | Not achieved the goals |
| 8 | Support least | 29% | Weak | Not achieved |

| | | | | |
|---|---|---|---|---|
| | developed strategies | | | the goals |
| 9 | Reduction of disaster strategies | 29% | Weak | Not achieved the goals |
| 10 | Support positive economic | 30% | Weak | Not achieved the goals |
| 11 | Interlink to policy making | 21% | Weak | Not achieved the goals |
| | Average result | 25% | Not achieve the goals | Not achieved the goals |

## 1.7. The research Conclusions

The research outcome is summarized in table 2 and figure 18.

**1.7.1.** The research outcomes is finding general framework assessment Method to Evaluate Greater Khartoum in SDGs, No.11 in all categories under sustainable city. Which are: providing Safe affordable housing and basic services, Sustainable transportation, Sustainable home settlements in the three towns, Protect culture and Natural Heritage, Reduce Waste including water, air and solid waste, Public access, Green space, Support positive economic, social and environmental links between urban and rural areas, National and local disaster risk reduction strategies, Interlink ages and implications for policy-making.

**1.7.2.** Reporting the present situation, challenges and future plan for each indicator.

**1.7.3.** Providing monitoring for the present achievements for each indicator in SDGs applied in Greater Khartoum.

**1.7.4.** Providing sustainable affordable houses and use of local building materials.

**1.7.5.** Applying the WHO standards for potable water regular maintenance and improvement.

**1.7.6.** Applying energy efficiency plans and policies including solar energy system for housing and industrial sectors by the government and the stockholders.

**1.7.7.** The priority for improvement is applying a better education, improvement the buildings quality, providing libraries with good numbers of books, eBooks, digital libraries, encourage the students for reading and writing researches, good activities such as sports and community participation.

**1.7.8.** For hospitals good solutions for the future are building up efficient hospitals by supporting and help of investors.

**1.7.9.** The priority for improvement is applying efficient bus station, subway, central bus station, efficient bridges and ring roads.

**1.7.10.** The priority for improvement is applying high-rise buildings and providing green space at the cenre of Greater Khartoum.

**1.7.11.** The research recommends protecting the historical and cultural places; by record them in Khartoum strategic plan, regular maintenance, and record them in UNESCO world heritage places.

**1.7.12.** Reducing solid, water and gaseous waste, set up regulations for people, and companies to manage the waste will be effective.

**1.7.13.** Public access, to the green space in different levels of the urban, indoor garden, intermediate green space at the middle of the neighbourhoods, and large green space and smart public space at the middle of the city.

**1.7.14.** Providing solutions for local disaster, reduce risk, and provides strategies, Set -up strategies in managing, the disaster especially in flooding season will be effective.

**1.7.15.** Supporting least developed countries, by providing suitable, healthy homes and services to them, allocate the land, encourage youths to build their homes, and learn them small projects.

**1.7.16.** Linking the SDGs to local urban planning policies and to policymaking strategies.

## 1.8. Acknowledgements

This research acknowledges to Dar Al Uloom University, for their continuous help, and to Sudan Sustainable Building Council, especially regulation and rating system team.

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**Table 1.3: The assessment method to evaluation the Sustainable City indicators according to SDGs**

| No of indicator | Focus indicators | The Evaluation range | | | | | The evaluation |
|---|---|---|---|---|---|---|---|
| | | Strongly disagree<br>0% - 24% | Disagree<br>25%-49% | Average<br>50% | Agree<br>51-75% | Strongly Agree<br>76%-100% | Evaluation from 5/5 |
| | | | x | | | | |
| 1 | Safe affordable housing | | | | | | |
| | Do the government Apply of Global building standards? | | | | | | 1/5 |
| | Apply of Local Sustainable Building Standards | | | | | | 1/5 |
| | Healthy houses are built up by the | | | | | | 1/5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | stockholders | | | | | | |
| | Affordable Houses are provided by the government | | | | | | 1/5 |
| | Use of Local Building Materials | | x | | | | 1.25/5 |
| 2 | Services | | | | | | |
| | Water efficiency | | | | | | 1/5 |
| | Energy | | | | | | 1/5 |
| | Efficient education | | | | | | 1/5 |
| | Efficient hospitals | | | | | | 1/5 |
| 3 | Sustainable transportation | | | | | | |
| | Do we have proper Bus station | | | | | | |
| | Encourage bicycle riding | | | | | | 1/5 |
| | Sub-way rail or electrical are available for people | | | | | | 1/5 |
| | Provide central stations | | | | | | 1/5 |
| | Effective Bridges | | | | | | 1/5 |
| 4 | Sustainable homes | | | | | | |
| | Provide High rise Buildings and office tower at the center | | | | | | 1/5 |
| | Increase the green outdoor spaces | | x | | | | 1.25/5 |
| | Provide smart outdoor spaces | | | | | | 1/5 |
| 5 | Protect culture and natural heritage | | | | | | |
| | Do the government (By ministries) record the historical places? | | | | | | 1/5 |
| | Are Registered in the local Urban Master Study plan | | | | | | 1/5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | by the ministry of urban planning | | | | | | |
| | Register them in UNESCO | | | | | | 1/5 |
| | Do the government offer through Ministries regular maintenance to historical places | | | | | | |
| 6 | Reduce Waste disposal | | | | | | |
| | Do you think that people manner is the basic problem of the waste | | | | | | 5/5 |
| | Do you think that waste management should support by regulations | | | | | | 5/5 |
| | Do you think that we should apply clear standards in waste disposal | | | | | | 5/5 |
| | Metering system is applied at home by Government | | | | | | 1/5 |
| | Efficient equipment is used by stockholders | | | | | | 1/5 |
| | Do you think that waste disposal handling should be by private sector? | | x | | | | 1.5 |
| 7 | Public access, Green space | | | | | | |
| | Provide outdoor green space | | | | | | 1.5/5 |
| | Provide smart public space. | | | | | | 1.5/5 |
| | Do you have private garden in | | X | | | | 1.5/5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | your home? | | | | | | |
| | Do you have semi-public green area at the center of your neighborhood? | | | | | | 1/5 |
| | Do you have public green space at the center of your city? Open to everyone? | | | | | | 1/5 |
| 8 | National and local disaster reduction strategies | | | | | | |
| | Provide protection to areas suffering from River Flooding | | x | | | | 1.25/5 |
| | Provide strong building materials for damaged houses | | X | | | | 1.25/5 |
| | Clear plan and strategies for diction making | | X | | | | 1.25/5 |
| 9 | Support least Development countries | | | | | | |
| | Provide affordable land and houses | | X | | | | 1.25/5 |
| | Learn the youth to build their houses | | X | | | | 1.25/5 |
| | Learn the youth to work in small projects | | X | | | | 1.25/5 |
| 10 | Support positive economic, culture and environmental links to ruler areas | | | | | | |
| | Do you support positive economic, social and environmental links between urban and | | | | | | 1.5/5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | rural areas | | | | | | |
| | Do you Increase the industry in rural areas | | | | | | 1/5 |
| | Do the government Provides fast and efficient roads | | x | | | | 1.25/5 |
| | Provide central markets | | | | | | 1/5 |
| | Provide cold and dry stores | | X | | | | 1.25/5 |
| 11 | Interning ages and support policy making | | x | | | | 1.25/5 |
| | Are you share in policymaking | | | | | | 1/5 |
| | | | | | | | |

Source: Adapted by the researcher

# CHAPTER TWO

# SUSTAINABLE ECO-NEIGHBOURHOOD

# Sustainable -eco -neighborhood assessment method in residential neighborhood in Greater Khartoum

## 2.1. Abstract


This paper investigates the present situation of low to medium rise buildings for medium class professors, teachers and doctors in residential areas in Greater Khartoum such as the Ecological Neighborhood, addressing questions like whether they are ecologically designed, how they can be evaluated and to what extent, the problems and issues in such evaluation and the solutions therefore.

To evaluate these Neighborhoods, the researcher has to adopt a rating system; for this purpose, a comparison was made with LEED v3 for Neighborhood development, which has been in vogue since 2009 and evaluates subjects using sustainable environmental parameters. This research studies three neighborhoods in Greater Khartoum, which are Residential Villas, Arrak City and El Naser Apartments. This study devises a system known as SENAM, for evaluating the Eco Neighborhood efficiency in a hot dry climate such as Greater Khartoum. SENAM evaluates nine main categories which are: Sustainable Site, Neighborhood Design, Pattern and Construction, Waste Management system, Materials and Resources, Water Supply, Power Supply system, Environmental Plan process, Health and Safety and Emissions and Community Participation . The total points for the various categories is 113 and the system offers four main certifications: (35

- 44 pts) Pass, (45 – 59 pts.) Good, (60 - 75 pts) Very Good, (76-132) pts or more) Excellent. The results would also be evaluated, analysed and discussed as per global parameters for sustained evaluation, such as LEED for Neighborhood development.

The research finds that: Residential Villas score 38% (certified), Arrak City 29% (not certified) and El Naser Apartments 51% (silver). *The analysis shows efficiency in Neighborhood Design, Pattern and Construction (40%), and Waste Management System (40%).

The analysis shows inefficiency in designing, sustainable site (30%), Materials and Resources (20%), and services, such as Water Supply System (27%), Power Supply (20%), Emissions (33%) and Community Participation (27%).
The Researcher has applied the Suggested Sudanese Sustainable Rating Systems (SSRS) in the eco neighborhoods in Greater Khartoum.

*Keywords*: The definition of ecological neighborhood, Principle of Designing Ecological Neighborhood, Sustainable Eco Neighborhood Assessment Method, (SENAM) to evaluate the Ecological Neighborhood.

## 2.2. Introduction

The importance of Sustainability has been recognized in 1992 at the United Nation Conference on Environment and Development, the "Earth Summit", held at in Rio de Janeiro, Brazil. The central aim was to identify the principles of action towards "sustainable development". Agenda 21 on" Promoting Sustainable Human Settlement Development" lays down that people should enjoy healthy sustainable neighborhoods to live in to meet with the global standards and to meet their own needs, with mixed use center, efficiency in water supply system, efficiency in power supply system, maximization of open spaces, green ecological buildings, and sustainable transportation system, waste management, etc. The researcher visited some of the new neighborhoods and compounds for residence in Grater Khartoum and noticed serious problems in the orientation of the buildings and on the services available in these neighborhoods, finding these solutions still far away from sustainable ones. This situation was compared to the one in global projects like AL Masdar city in Abu Dhabi, Bedzin Green project in UK and Siviano green project in USA.
This paper investigates the present situation of Ecological Neighborhoods in Greater Khartoum, to assess whether they are sustainable ecological neighborhoods and if so to what extent, the problems faced by them and possible solutions therefore. Accordingly, the researcher designed a rating system to evaluate three neighborhoods in Grater Khartoum by comparing them to global systems.

***Historical Background***

**LEED for neighborhood development and others.**

**LEED v3** for neighborhood development came into vogue in 2009 and consists of five main categories, which are: smart location, neighborhood design and pattern, green infrastructure and buildings, Innovation in design process and regional priority.

There are many Global green building councils around the world, some of which set up the Neighborhood rating system like LEED for neighborhood development. Similarly, QSAS for neighborhood was started in 2010, while ESTEDAMA, which added the liveable community category including some points to evaluate the neighborhood, also started in 2010.

LEED for neighborhood development is applicable to many projects and it is easy to connect to United States green building council to manage your design, as the service is available through the internet.

However, LEED for neighborhood development rating system does not include parameters like health, safety, emission category, community participation and environmental process as main categories and energy efficiency, water efficiency as waste management as separate categories. **LEED announced LEED V4 for Neighborhood development including more flexibility with strategies to fit the unique aspects of your project, performance based design, operation and design, smart grid and networking approach, material and resources, water and streamline documentation. (U.S.G.B.C, 2017)**

Through this paper, the researcher will provide a sustainable assessment method suitable to a hot dry climate such as Greater Khartoum, in order to evaluate the Eco Neighborhood in Greater Khartoum and this system will include all relevant parameters like energy efficiency, water efficiency, ecological building materials according to available natural resources and other parameters applicable to a hot, dry climate.

The researcher expects to answer the research questions by applying this system to three case studies and evaluating the results. In addition, the system will evaluate this situation vis-a-vis sustainable environmental parameters and identify the problems and solutions therefore. This paper will also suggest a Sudanese Sustainable Rating System to evaluate ecological neighborhood through the methodology of this research.

**Rieck, A.** (2012) discussed Masdar city in Abu Dhabi, and stated that the new green cities is about how we can control nature and highlighted such parameters for new green cities like: Energy Consumption, Energy storage, Transportation system, Waste Management, Mobility, Information Technology and Communications Technology.

**Peled, G.** (2008) discussed the new Jerusalem eco housing project and some categories of eco neighborhood, viz., Energy Conservation, Waste Reduction, Water Conservation, Land Use, Transportation, Community Involvement, Health and Safety, Disaster Control, Wellbeing, Materials and Recycling, Urban Ecology and Footprint.

**Alderson, A.** (2005) highlighted important categories for Eco- Village in Scotland, UK, like Energy, Telecommunications, Water and Sewage, Location, Solid Waste, Transportation, Ecological Environment, Design and Building, Economy and Social Issues and Education.

**Riis, C.** (2014) discussed in her paper about Green Strategies in Copenhagen, designated as the European Green Capital in 2014. The concept takes into account the urban life scale before building scale, strategic urban development on a large scale, urban development and site specific plans in the medium scale and in the small scale, considers other ideas and projects, as for example Green pathway, Green roof and Green backyards.

**Definition of Ecological Neighborhood**

United State Green Building Council defines Neighborhood Development thus: "integrates the principles of smart growth, urbanism and green building into the first national system for neighborhood design'. U.S.G.B.C (2012). It provides the balance between the income and food, renewable energy, goods, materials and the outcome of organic waste recycling, materials recycling, minimize pollution and waste and emissions. See Fig. 2.1.

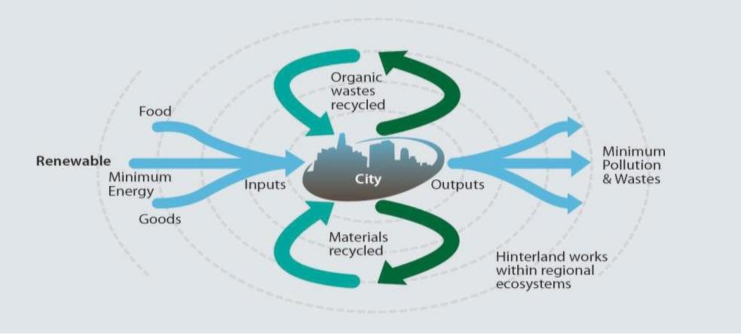


**Figure 2.1: Circular metabolism: Cities reduce consumption and pollution, recycle and maximize renewables, Source: Ben Hamadou, R. (2012).**

**Theory of Traditional Neighborhood** walking distance: The traditional neighborhoods' typology comprises a compact residential area with a variety of housing types and services like small shops, libraries and mosques and churches. The ideal size of a neighborhood falls within the 1/4-mile measurement (400m.), which is the distance the typical adult can walk from centre to edge in approximately five minutes.

Mixed use center: The second theory of the traditional neighborhood says it should provide for mixed use, areas of concentrated activity – living, working, learning, playing, eating, and shopping, designed to accommodate pedestrians and transit use in addition to auto travel. See Figure 2.2

Neighborhood centers are mixed-use activity points scaled to serve a trade area with a radius of less than three miles. Larger neighborhood centers typically include a full- service supermarket or grocery store and serve no less than six neighborhoods, with parking, Malls, etc.

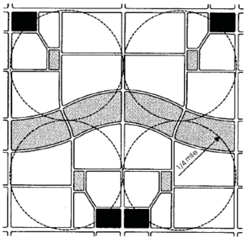


**Figure 2.2: Traditional neighborhood combination diagram: (Drawing: Courtesy: Duany Plater-Zyberk And Company. Source: Walters, D. and Luise Brown, L. (2004)**

Study of the Master Plan: The Master Plan should focus on a three-dimensional urban form, instead of two-dimensional plan diagrams that indicate land use only., which is the key message of the book Three dimensions are better than two by Walter (2004). Three-dimensional infrastructure of form and space allows long-term flexibility of use and operation. These issues include the impacts of changes in technology, social structures, economics, uses, architectural styles and development practices.

**Theory of Sustainable Neighborhood**

UN HABITAT (2009) stated the environmentally sustainable urbanization requirements reduce greenhouse emissions, minimized and compact cities and use renewable resources. Figure (2.3) shows a conceptual idea of mixed uses in a self-contained walkable neighborhood node, Jenks, M. and Dempsey, N. (2005) stated that social, economic, and environmental justice depends heavily on mass transportation to incorporate a percentage of low-to-moderate-income families into every neighborhood node.

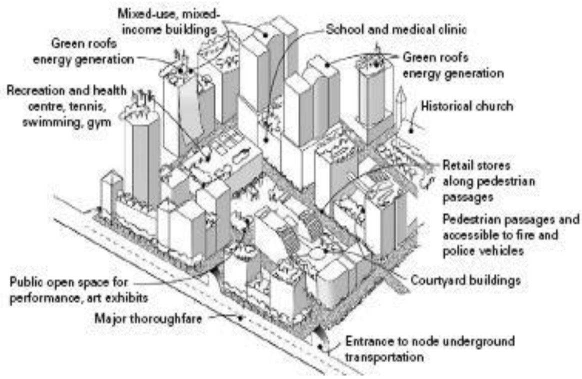


**Figure 2.3: A conceptual idea of the mixed uses in a self-contained walkable neighborhood node. SOURCE: (Jenks, M. and Dempsey, N. (2005)**

People are critically needed. Fire-fighters, police, health care workers, labourers, and food suppliers must live in close proximity, in order to provide immediate help. It should be a self-contained community that provides for schools, health care, police, fire protection, postal services, banking, open spaces for playgrounds and parks within walking distance.

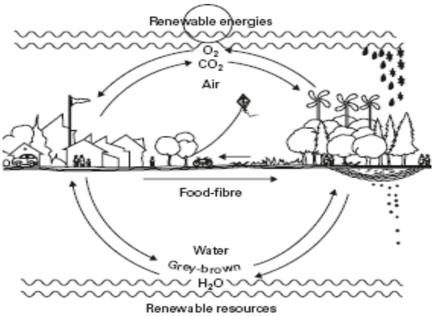


**Figure 2.4: Sustainable cells of urbanization, SOURCE: Jenks, M. and Dempsey, N. (2005)**

Sustainable cell is provided a balance between human activity in human–environmental systems (HVAC _Heating Ventilating and Air-Conditioning) waste with the surrounding environment as well as human health with environmental systems of air, water, food, fibre (land), and energy for the community are modelled and measured to establish indicators for sustainability. See Figure (4). Jenks, M. and Dempsey, N. (2005) and Sassi, P. (2006).

## Focus on Khartoum Conditions

### Khartoum location

Abu Sin and Davis, (1991) wrote that Khartoum state straddles the confluence of the Blue and White Ni1e that covers some 28,000 square kilometers and covers about 2.17% of the total area of Sudan. It lies at latitude 15° 36' north and longitude 32° 3 east, with an altitude of 380 meters above sea level. El Agraa, O.M. and Shaddad, M.Y. (1988) discussed the location of Khartoum too. Khartoum was first made the capital of the Turkish-Egyptian rule in the 1830s.

### Environmental factor

Khartoum faces four climates:

Rainy season in the autumn, with precipitation ranging between 150 mm and 200 mm.

In summer, the wind direction is South-South East and in winter, it is North and North – West.

The temperature: In summer, it ranges from 40°C to 50 °C, and in winter, between 10°C to 25°C.

Humidity ranges between 20% in summer to 40% in winter.

Natural resources: Khartoum is rich in solar energy, wind energy, biomass energy and geophysical energy, as well as hydroelectric energy.

### Political factor:

Sudan has subscribed to several international Agreements, starting with Agenda 21 in 1992, the Kyoto protocol, the United Nations Framework Convention on Climate Change (UNFCCC) and has a working relationship with UN- HABITAT, UNEP, UNDP and NGOs, to establish sustainable projects in SUDAN.

Social factors: Earlier studies showed that Khartoum population is increasing and may have doubled in the last 20 years, to the level of 5,500, 000 according to the last census. Reasons for the increase include increasing migration towards Khartoum city, which affects services such as education, health, transportation, the quality of housing and waste management in Khartoum.

To provide and design a sustainable neighborhood in Khartoum, we should consider all this information, taking into account the traditional and sustainable principles of designing an ecological neighborhood. This will be discussed while considering the methodology of this research.

## 2.3. The Methodology

- The researcher has undertaken a wide literature review, to identify the main principles of sustainable eco neighborhood. Global standards leader LEEDV3 for Neighborhood and development (Leader in Energy and Environmental Design) applied criteria like smart location, neighborhood pattern and design, green infra structure and building, innovation in design and regional priority categories. On the other hand, The Environmental Assessment Method (BREEAM, 2017) applied categories like energy, health wellbeing, land use, pollutants, waste, ecology, innovation, materials and water, with different details and sub-issues.
- The researcher identified the main categories to be applied in a hot dry climate like Greater Khartoum. These are: Sustainable Site (30 points), Neighborhood Design, pattern and construction (39 points), Materials and resources (5 points), waste management system (5 points), water supply system (5 points), power supply system (4 points), Environmental process (1 point), health, safety and emissions (5 points), with details and sub issues indicated in table 1 of the Appendix.
- The researcher added additional categories like Environmental design process, health safety, emission and community participation. The community in Greater Khartoum needs to be educated about sustainable design and involve itself in improving the environment. These additional categories were discussed by the researcher in a previously published scientific paper (Abdelmoneim, H., 2016).

- Comparison between the research method of assessment (Sustainable Eco Neighborhood Assessment Method, SENAM) and LEED for neighborhood development.

Figure 2.5 shows the difference between the research method of assessment (Sustainable Eco Neighborhood Assessment Method, SENAM), which has nine main Categories, carrying weightage as follows: Sustainable Site (30 points), Neighborhood Design, pattern and construction (39 points), Materials and resources (5 points), waste management system (5 points), water supply system (5 points), power supply system (4 points), Environmental process (1 point), health, safety and emissions (5 points) and community participation. Figure (4.6) shows LEED for Neighborhood Development which contains five main categories, which are: Smart Site (27 points), Neighborhood Design and pattern (44 points), Green Infrastructure (29 points), Innovation in design (6 points) and Regional priority (4 points).

The researcher added Waste management, Material, Energy, Water and drainage system, Environmental Design Process and Community participation as new categories to the Sustainable Eco Neighborhood, for a more comprehensive evaluation.

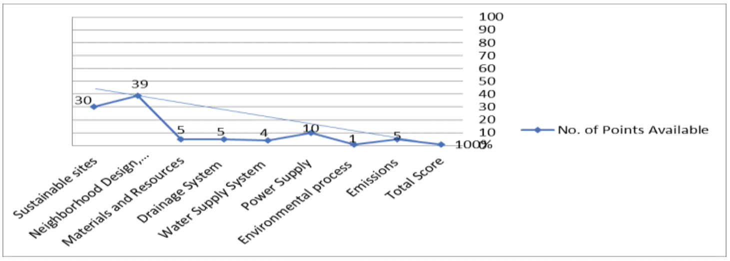


**Figure 2.5: Sustainable Eco Neighborhood Assessment Method, SENAM, Source: Designed by the researcher**

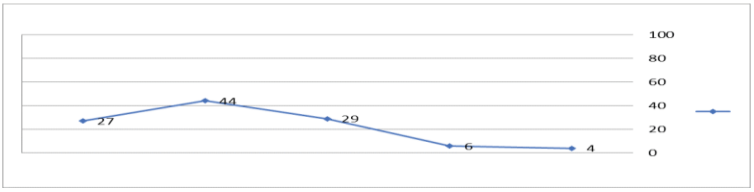


**Figure 2.6: LEED V3-Neighbourhood Development, Source: LEDD for Neighborhood Development (Designed by the researcher)**

**Summary of the Assessment System Applied on Eco Neighborhood:**

- Weightage, credits and percentage points:

**Table 2.1: Weightage, credits factors**

| The Category | The average result | The Average Result by LEED ND, V3 | The evaluation BY SENAM |
|---|---|---|---|
| Sustainable site | 30% | Not certified | weak |
| Neighborhood Design, pattern and Construction | 40% | certified | pass |
| Materials and Resources | 20% | Not certified | weak |
| Waste management system | 40% | certified | pass |
| Water Supply System | 27% | Not certified | weak |
| Power Supply | 20% | Not certified | Weak |
| Environmental process | 60% | good | good |
| Emissions | 33% | Not certified | Weak |
| Community participation | 27% | Not certified | weak |

Source: Designed by the researcher

- The scale system

**Table 2.2: The scaling system**

| The Mandatory | Mean | Points availability |
|---|---|---|
| Yes → | Means it's applicable | |
| | The most Positive impact | 3 |
| | More Positive impact | 2 |
| | Positive impact | 1 |
| No → | Means it's not applicable | 0 |
| | Negative impact | -1 |

Source: Designed by the researcher

- The System Certifications

This system gives four main certifications:

*< 35 weak,*

*(35 - 44 pts) pass*

*(45 – 59) good,*

*(60 - 75 pts) very good*

*(76-111pts or more) Excellent*

## 2.4. The Field Work

### 2.4.1. The Locations

The research studies three Neighborhoods in Khartoum, which are Residential villas, Arrak City and El Naser Apartments.

See the site location in Fig. 8, Fig. 9 and Fig. 10 and Fig.11.

### 2.4.2. Standard of selection of the case studies

New Neighborhoods and new urban planning areas. See satellite images. They applied new approaches in design concepts and environmentally sustainable ecological design, which had just been adopted in the 1990s and which took into account the Eco Design principles and the main categories. They were built by famous Consultant companies. Looking for applying Sustainable Neighborhood Cell. The researcher was looking for proper technical solutions in services. Water supply, waste management and drainage system. Energy System. Site security and health awareness. Building materials were recycled and eco-friendly building materials. Looking for applying the latest new technologies in the field of eco design. Outdoor environmental control. Diversity in house type. Ecological treatments.


**Figure 2.7: The Location of Residential villas near the River Nile, Khartoum City, Sudan.** Source: Google image 2017


**Figure 2.8: The second location is Araak Neighbourhood , Madani street , Khartoum City, Sudan**. Source: Google image 2017


**Figure 2.9: The third location is Al Naser Neighbourhood , Africa street , Khartoum City, Sudan**. Source: Google image 2017

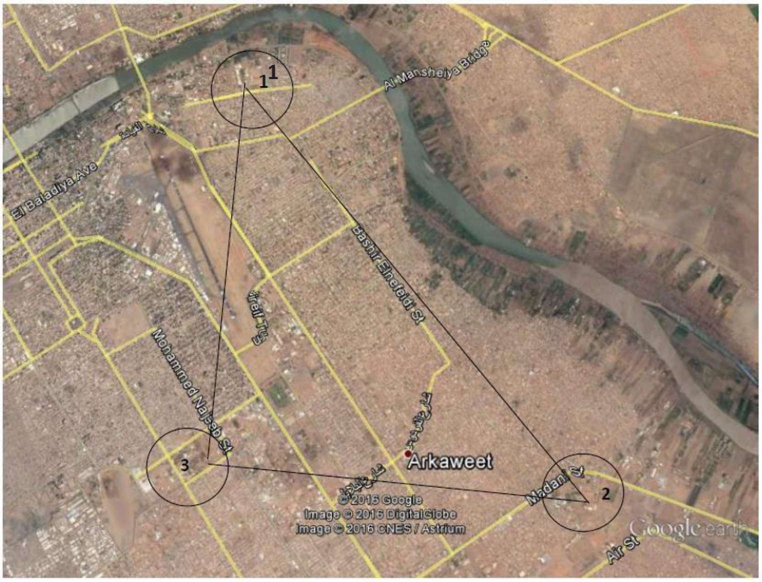


**Figure 2.10: The three locations in perspective: Residential villas, Araak City and Al Naser Apartments**, Source: Google image 2017.

### 2.4.3. The application of (Senam) to the case studies

The researcher applied the Sustainable Eco Neighborhood Assessment Method-SENAM to evaluate the three neighborhood case studies.

### 2.4.4. Updates of the case studies

In June 2017, the researcher started to make updates to the case studies and as per his supervisors' instructions, he visited all the cases, starting with the research studies in the three neighborhoods in Greater Khartoum, viz., Residential villas, Araack City and Al Naser Apartments. She found that most of the sites had not changed and no sustainable solutions had been added by stockholder.

## 2.5. The Results

The summary of the results of three case studies on the level of eco neighborhood is presented in Appendix -1, and the result of each case study on the level of eco neighborhood presented is presented in the following Tables and Figures.

**Case Study-1, the Residential Villa Type-B**

**Figure 2.11** shows the result of the analysis of case study of the Residential Villas neighborhood and the results were as follows:

Sustainable Sites 23%, neighborhood design, pattern and construction 38%, materials and resources 20%, waste management system 40%, water supply 40%, power supply 17% environmental process 60%, emissions and safety 60% the community participation 27%. Total result was **39%**.

**Case study-2 (Arak City villa type-D)**

**Figure 2.12** shows the result of the analysis of case study two on the level of neighborhood. Sustainable Sites 13%, neighborhood design, pattern and construction 23%, materials and resources 20%, waste management system 40%, water supply 20%, power supply 25%, environmental process 50%, emissions and safety 20%Community participation 7%.The total result was **29%**.

**Case study-3 Al Naser Apartments**

**Figure 2.13** shows the result of the analysis of case study three on the level of neighborhood. Sustainable Sites 53%, neighborhood design, pattern and construction 60%, materials and resources 20%, waste management system 40%, water supply 20% power supply 17%, environmental process 70%, emissions and safety 20% the total Community Participation 27%.

Result was 51%.

### 2.5.1. The Results Shown in tables

The Result of the case studies on the Level of Neighborhood.

See Table 3 and table 8 and figure 11 to 14.

### 2.5.2. The result of each neighborhood in figures


**Fig. 2.11. The results of Residential Villa Neighborhood**

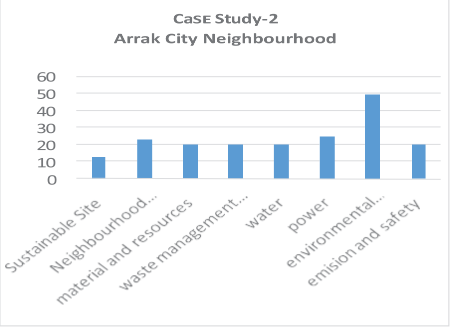


**Fig. 2.12. Arraak City Neighborhood**

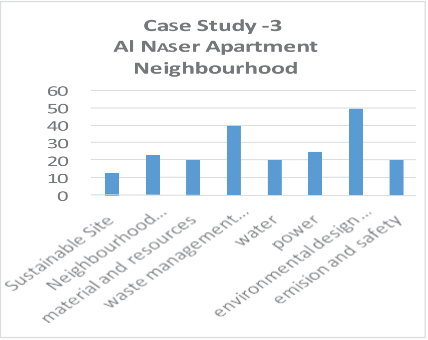


**Fig. 2.13. The results of Al Naser Apartments Neighborhood**

**Average Results:**

**Table 2.3: THE AVERGE RESULTS OF MAIN CATEGORIES**

| Case Studies | Sustainable Site | Neighborhood Design, Pattern and construction | Material | Water Supply System | Waste Management | Power Supply System | Health Safety And emission | Environmental Design Process | Community Participation |
|---|---|---|---|---|---|---|---|---|---|
| Residential Villa | 23 | 38 | 20 | 40 | 40 | 17 | 60 | 60 | 27 |
| Araak City | 13 | 23 | 20 | 20 | 20 | 25 | 20 | 50 | 27 |
| Al Naser Apartments’ | 53 | 60 | 20 | 20 | 40 | 17 | 20 | 70 | 27 |
| Average result | 30 | 40 | 20 | 27 | 33 | 20 | 33.3 | 60 | 27 |

THE AVERAGE RESULTS OF MAIN CATEGORIES IN FIGURES

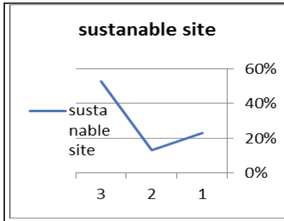


Fig. 2.14. The Average result of Sustainable site

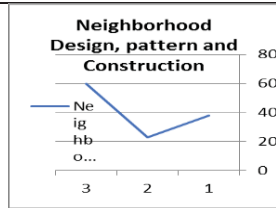


Fig. 2.15. The Average result of Neighborhood, Design, Pattern and construction.

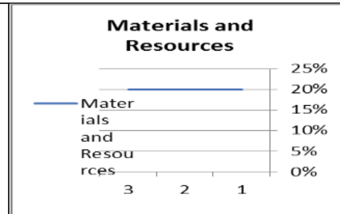


Fig. 2.16. The Average result of Material and Resources.

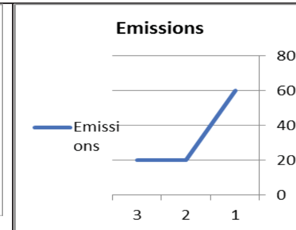


Fig. 2.17. The Average result of Emissions

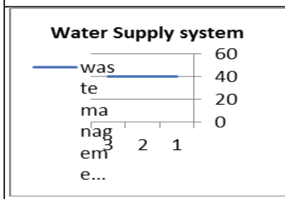


Fig. 2.18. The Average result of Water supply system.

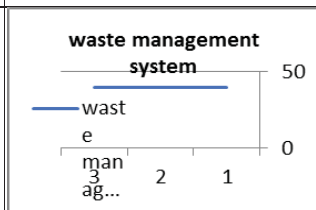


Fig.2.19. The Average result of waste management system

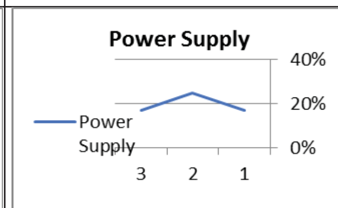


Fig. 2.20. The Average result of power supply

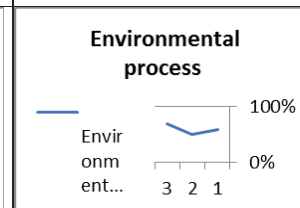


Fig. 2.21. The Average result of environmental process

## 2.6. Discussion of the Results

The discussion has two parts.

**Part one**: The discussion the results for each neighborhood.

The research has identified nine main categories of Eco Neighborhood, which are: sustainable site, neighborhood design and pattern, materials and resources, drainage system, water supply system, power supply, emissions and safety procedure, environmental design process and community participation, as explained in the Method. The researcher proposes environmentally sustainable tools for Eco Neighborhood, suitable for hot dry climates. The results were analyzed with SENAM

**Table 2.4: The system of evaluation**

| The Certification by SSRS | |
|---|---|
| <35 | Weak |
| (35 - 44 pts) | Pass. |
| (45 – 59) | Good. |
| (60 - 75 pts) | very good |
| (76-111pts) or > more | Excellent |

**Case Study-1, the Residential Villa Type-B**

Table 2.3 shows the result of the analysis of case study one on the level of neighborhood, with the weightage scores as per SENAM being as follows:

Sustainable Sites 23%, neighborhood design, pattern and construction 38%, materials and resources 20% , waste management system 40%, water supply 40%, power supply 17%, environmental process 60%, emissions and safety 60% the community participation 27%. Total result was 39%. This result is a “pass”.

The evaluation showed efficiency in designing a sustainable site, indoor environmental quality and outdoor thermal control, inefficiency in building form, materials, resources and services, such as drainage and water supply systems, power supply and emissions.

**Case study-2 (Arak City villa type-D)**

The Total Credit for the building was 35 % for villa type D.

The evaluation showed efficiency in designing a sustainable site, indoor environmental quality, inefficiency in building form, materials and resources, and outdoor thermal control and services, such as drainage and water supply systems, power supply and emissions.

The total result for the neighborhood was 29%, meaning weak result.

**Case study-3 Al Naser Apartment, one Building**

The Total Credit was 46 % for one apartment building type.

The evaluation showed efficiency in designing a sustainable site, indoor environmental quality, inefficiency in building form, materials and resources and services such as drainage and water supply systems, power supply and emissions. The score indicates "Good".

Result was 51% for the neighborhood.

This result is good.

**Part two**: discussion of the average result among the three neighborhoods.

## 2.7. Discussion of the Average Result

### 2.7.1. Sustainable site

**Table 2.5: The certification system of SENAM and LEED V3 for Evaluating Eco Neighborhood**

| The Category | The average result | The Average Result by LEED ND, V3 | The evaluation BY SENAM |
|---|---|---|---|
| **Sustainable site** | **30%** | **Not certified** | **weak** |
| **Neighborhood Design, pattern and Construction** | **40%** | **certified** | **pass** |
| **Materials and Resources** | **20%** | **Not certified** | **weak** |
| **Waste management system** | **40%** | **certified** | **pass** |
| **Water Supply System** | **27%** | **Not certified** | **weak** |
| **Power Supply** | **20%** | **Not certified** | **Weak** |
| **Environmental process** | **60%** | **good** | **good** |
| **Emissions** | **33%** | **Not certified** | **Weak** |
| **Community participation** | **27%** | **Not certified** | **weak** |

The result of sustainable site is 30 % in the scale mentioned above, indicating the result of evaluation as “passing”. It can be noticed from Figure (13) that Al Naser Apartment has a good neighborhood design and and U -shaped pattern, with the building and site orientation being certified as good. However, the neighborhood failed in providing the other solutions like local food production, diversity in housing type, neighborhood mix used Centre.

### 2.7.2. Neighbourhood, Design Pattern and Construction

The result of neighborhood design and pattern is 40 % in the scale mentioned and is evaluated as good. It can be seen from Figure 14 that Al Naser Apartment has a good neighborhood design with a U shaped pattern and a good building design.

### 2.7.3. The Materials

The score relating to the material is 20% and indicates a “weak” valuation. It is noticed from Figure 15 that Arack City Residential villas utilized eco building material in construction, like recycled building materials, eco cement, eco building materials, earth stabilized bricks, etc.

### 2.7.4. The water supply

The result of the water supply is 27%, signifying a “weak” value. We notice from Figure 17 that Residential Villas present a good solution in providing local water treatment station plant with highly efficiency. On the other hand, the other two sites provide poor solutions, with water being provided from the National Grid, which does not meet WHO standards for potable water. We need to increase the efficiency in water treatment, and we need to provide each neighborhood a local water treatment plant, and adopt such solutions as rain water harvesting, recycling of grey water for irrigation, etc.

### 2.7.5. The Waste Management

The result of the waste management is 40, which indicates “pass”. It is noticed from Figure 17 that all the case studies followed the same solution in drainage system which consists of a well and septic tank. This is the best practice solution at present in Greater Khartoum. Other solutions as biological treatment and surface run off are not found.

### 2.7.6. Power Supply

The result of the power supply is 20%, which is “weak”. It was found that Residential villas and Arack City used electrical generation room and underground cable, to avoid environmental hazards resulting from use of high tension cables. Other solutions like solar energy or wind energy are not found.

### 2.7.7. Emission

The average result is 33.3%, "weak". Compared to the result by LEED V3 for Neighborhoods Development, this result rates as "not certified". It can be noticed from Figure (16) that Residential villa provides good solutions in the buildings in controlling the gaseous emissions, through the provision of fire alarm system, smoke detectors, low green gas emissions and solid waste management. Such solutions are good in designing Eco Neighborhood. Araak City as well as Al Naser Apartments also provides exhaust fans in Kitchen and Bathrooms.

### 2.7.8. Environmental Design Process

The environmental design process is 60% and is evaluated as good. It is noticed from Figure (20) that Al Naser Apartments presented a good solution in environmental design. We should apply the environmental design process from the initial stages at all levels:

1-prebuilding phase

2-building phase

3-post building phase

Refer to chapter six, Figure 6.7

### 2.7.9. Community Participation

By comparing the average result 27 with the scale, this result rates as weak. Comparing the result by LEED V3 for Neighborhood Development this result rates as not certified. It could be noticed from Figure 21 that Al Naser Apartments, residential villas, Arak City, Provide the same level in community participation which includes investors and consultants and the government. We should engage all levels and partners who include architects, planners, engineers; suppliers and contractors, agents in order achieve sustainable development.

## 2.8. Conclusion

| | | |
|---|---|---|
| Residential villas | 39% | Pass. |
| Arrak City | 29% | Weak. |
| El Naser Apartments | 59% | Good. |

The research obtained different evaluations, of which El Naser apartments emerges as a good example on an ecological neighborhood, with neighborhood centre offering most of the services like sustainable site, care about safety procedures, a range of rising buildings with different solutions and variety in areas; these buildings have good ventilation and good orientation and provide economic value as well. Arak city failed because they didn't adhere to building orientation codes, nor did they provide a complete range of services for everyday activities in the neighborhood centre. The Residential Villas emerges weak in the results because there are 12 villas having inappropriate ventilation and orientation, along with a problem in the on-site drainage system. On the other hand, Residential Villa provides high safety, health, emission, telecommunication and services. Araak city offers good solutions for building design and services.

## 2.9. Recommendations

1. This study recommends managing the sustainable site, waste disposal system, water supply system, power supply and emissions, applying the principles of sustainable eco neighborhood assessment, to evaluate such neighborhoods in a hot, dry climate.
2. Management of the power supply system, with adoption of renewable resources such as solar energy and wind energy, is recommended for managing the power shortage, vis-à-vis the National Grid.
3. The research recommends use of local building materials and recycling technologies in building construction.
4. The water supply system should be augmented and made more efficient through adoption of WHO standards in water treatment to meet WHO Standards.
5. For the drainage system, the research recommends adoption of solutions like biological treatment, recycling of grey water to be used for irrigation and application of drainage net.
6. The research recommends adopting such solutions as shaft and filters in the kitchen, fire alarm system, smoke detectors, etc. and the use of clean energy to minimize $CO_2$ emissions.

7. Finally, we should apply an environmental design process right from the initial stage of the design.
8. The research recommends applying the principles of eco-neighborhood to such areas in hot, dry climates (See the applied sheet).

**Sustainable Site**

- **Smart Location, Control systems**.

  Enhanced parking control, Reduced Automobile Dependence, Bicycle Network, walkable Streets, Pollution control in construction activities, noise prevention, controlling natural water feature, avoidance of Floodplains.
- **Improvement of outdoor thermal environment**

• Heat Island effect, Enhancement of landscaping on site, Public Transport Access, Maximization of Open space,

• Universal Accessibility,

• Community Outreach and Involvement,

• Ecological Awareness.

- **Neighborhood Design, Pattern and Construction**

**Design:** Certified Green Buildings, Neighborhood strategies, Affordable Rental Housing, Building Reuse and Adaptive Reuse, sustainable Historic Buildings, Minimization of Site Disturbance through Site Design, Site Orientation, Local Food Production.

**Construction:** Construction Management, Minimization of Site Disturbance during Construction.

**Neighborhood Pattern:** Diversity of Housing Types, Access to Active Public Spaces.

**Street Network:** Reduce car parking, walking streets, Cycle parking, Transportation Demand Management.

**Ecological footprint:** Local Food Production, independent food stores, Reduce food waste, Eco-scape (ecological-landscape).

I. **Materials and Resources:** Recycled Content for Infrastructure, Eco Building Materials used for construction, Eco Concrete, eco recycled building materials, enhancement of proper technologies in building materials industries.
II. **Waste management system:** Ecological sanitation, Surface runs off, Recycling of grey water, on- site Sewage Treatment: Septic Tank System, Solid waste classification and recycling.
III. **Water supply system:** Efficient water supply system, conservation of rainwater, recycling of grey water, conservation of water consumption.
IV. **Power supply:** From the National Grid, Site electrical Station, Underground cable, generation of Solar energy, Solar energy heating system, solar energy cooling system, solar boiling, solar cooking, wind energy, availability of outdoor solar lighting, efficiency of Infrastructure Energy.
V. **Environmental plan Process**: Enhances environmental design process.
VI. **Safety and Emissions Systems**: Land, fire alarm system, security, smoke detectors, Low greenhouse emissions, solid waste management, waste recycling.
VII. **Community Participation:** In applying eco neighborhood principles, we should involve: the Government sector, Investors, Developers, Agents, Project Managers, Architects, Planners, Contractors, Suppliers, Owners and Users, to make sustainable development a broad-based, people-based initiative.
VIII. **The Environmentally Sustainable checklist and the certified:** From the case studies and the analyses, the researcher has arrived at the results of this research and come out with measures suitable for Sudanese environment and its prevailing conditions.

*< 35 weak:*

*(35 - 44 pts) pass.*

*(45 – 59) pts (Best Practice) (good).*

*(60 - 75 pts) (Very good).*

*(76-111pts and more) (Excellent)*

## 2.10. Acknowledgements

This humble effort would have never been possible without the help of others. I would like to thank my supervisors Prof. Saud Sadig Hassan, and Dr. Tallal Abdal Basit Saeed, for their continuous help and guidance, but for which this humble paper would never have been possible. In addition, I would like to thank Dar Al Uloom University for giving me the opportunity to publish my paper.

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**On The Level Of Eco Neighbourhood**
**Case Study-1**
**The Residential villas**
**and villa type-B**

**38%=PASS**

**Site Location:**
The compound located in east Khartoum centre in Garden City area, on the west bank of the Blue Nile river, 2.5 km North-east of Khartoum International Air Port
To select the site, the challenge was to comply with the following conditions:
Near Khartoum Air port
To be built in a quiet area
To prevent the noise as far as possible
To be near the republication Palace

**Hotel Service ClAssification:** 5 Stars.
**Infrastructure:**
40 Separated Villas Each Villa consists of
One suite.
5 Rooms.
Main lobby.
Family lobby.
Kitchen.
Roof.

Presidential Restaurant.
Presidential Hall.
Conference Room.
Health Club.
Swimming Pool.
Tennis court.
Party area.
Gardens.
TV Stations: 40 Channels.
Business Centre.
Wireless Internet Access.

**The lANDSCaping:**
The site is provided with a large number of different types of vegetations and plants: some are flowers and small are plants; others are large trees .
the architect used the trees to classify the site used area
and to give the site some privacy

**The public Space:**
This is the area in the middle and it includes the administration, restaurant services, the conference hall, the mosque, the swimming pool and the ni






Pl.(4.2.121) South Elevation


Pl.(4.2.122) North elevation


Pl.(4.2.123) Fumes chaff


Pl.(4.2.124) sensors

## Case Study-3
## The Al Naser Apartments complex
## 51%=GOOD

**The site Location:**
Elnasr Apartments complex are located west Afra Commercial Center, south 61 street , north, east Sudatel club east national park in Khartoum city. It's about five kilometer from city centre, two kilometer from Khartoum International Airport. It contain 28 buildings, and five different types, Type one 120m2, type two 145m2, type three 168m2 and the duplex 240 m².

**Areas:**
Site area=72000m2
Total Build up area =18500m2
Open spaces(parking area + green areas)=53500m2
Open spaces=42%
Buildup area ratio=25%
Number of buildings=35 buildings
Number of flats about 1000 flats

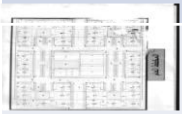
**Services**
Apartments
Parking area
Green areas
Super markets
Girls Primary school
Boys primary school
Mosque
Kindergarten
Clinic

**Negative points:**

There is no fire escape staircase .for each building
There is no shoot for waste in each buildings
Less green areas
Less plantation
There is no grey water treatment and recycling for plantation

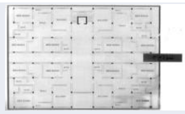
There is no natural resources power supply system
There is only semi private and public open space , the company should add a privategreen terraceto each flats
There is no fire alarm system for each floor
Thesuper market should beat the centreof thesite.

**Positive points:**
Site security
Complete services
Good parking area
The good evaluation of this site in comparison by other two sites
The good cross ventilation and orientations for all types
There is a main electrical station inside the site
A good u - shape cluster it and provides a privacy to each zone



Pl.(4.2.133): Elnasr Apartments Site Plan


Pl.( 4.2.134): The ground floor plan of type- 4 ( Duplex), 240m²



Pl.( 4.2.135): The plan of type -3 , 168m²

Pl.( 4.2.136): The plan of type-3 , 168m²

Pl.( 4.2.137): The plan of type-1 ,

Pl.( 4.2.138): The plan of type -1 , 120m

Pl.( 4.2.139): The plan of type -2 , 144m2

Pl.( 4.2.140): The plan of type-2 , 144m2

## Case Study-2
## The Araak City and villa type-D
## 29%=WEAK

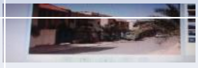
**The Location**
The city is distinctively located in south east khartoum, within the suburbs of cap ital, off the junction of Sixty Street and Wad Medani Road (main highway linking Khartoum and the major cities).
The centre of Khartoum is easily accessible with the airport only 4km away
Araak City is made up of five residential districts spanning an area over 200,000m2 with 510 villas and 420 apartments of different styles and sizes.
An area of 15,000m2 is allocated as a park that

**Services**
Araak City is clearly identified by its green areas, well-furnished roads and ready infrastructure. It has been constructed in a manner to ensure that the services foster a healthy lifestylewith families in mind. They includestate-of-the-artleisure facilities, a shopping area and children's playground.
Araak City's modern utilities include:
Independent Water Network
IndependentElectrical Network
Telephone Network
Irrigation Network
Sewage System (well+septictank)
Private Parks
Well-lit asphalt roads
Planted pavements
Sidewalks
Araak club

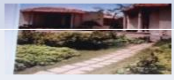
**Specifications:**
The villa plans were carefully designed to provide a functional, yet comfortable home catering to the needs of each member of your family. Different villa layouts and different villa sizes ensure that you'll find your perfect home.
Only the highest quality materials were used in the construction and finishing of the villas to guarantee, only the finest standards.
Some of the many unique characteristics and beautiful finishing touches of the villas:
Highest Quality Marble floors for all halls, kitchens, staircases.
Security Front Doors with beautiful wooden architraves

Elegant Cornices line the interior walls.
Complete fully fitted Kitchen with cooker and refrigerator.
Split Unit Air Conditioners in all Halls and Bedrooms.
Fully Fitted Bathrooms installed with Water Heaters.
Private Front Yard or Back Garden.
Separate Housekeeper Living Quarters.
Parking Garage.

Pl.(4.2.125) site location



Pl.(4.2.126): Araak city



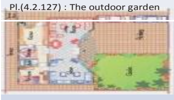
Pl.(4.2.127) : The outdoor garden

Pl.(4.2.128): villa type B

Pl.(6.2 -

Pl(4.2.129): Type –D loca tion in Araak

Pl.(4.2.130): The Main Elevation,



Pl.(4.2.131): Villa Type-D Ground Floor Plan

Pl.(4.2.132): Villa Type-D First Floor Plan

# CHAPTER THREE

# SUSTAINABLE-ECO-BUILDINGS

# Sustainable-Eco-Buildings Assessment Method for The Evaluation of Residential Buildings in Hot dry Climate

## 3.1. Abstract

This research aimed to investigate the present situation of residential buildings in Greater Khartoum. The area of study was in the four urban classes in Greater Khartoum. The problems of residential buildings in the indoor and outdoor environment and services were examined, to find a sustainable assessment method to evaluate residential areas and their services in Greater Khartoum.

The methodology of the research started with a literature review, identifying the passive and sustainable solutions suitable to hot-dry climate. This method contains eight main categories, which are, sustainable site, indoor environmental quality, outdoor thermal control, building form, materials and resources, water supply, power supply system, and environmental plan process.

The method has a points scale, as follows: Excellent, V. Good, Good, and Pass, and the total points achieved should be 125 points. Points were computed for the main categories and sub-issues to calculate the total points to arrive at the result of evaluation for the building.

The survey began by identifying the standards of selecting the case study, tools of investigation and the documentations methods, interviews with professionals and owners; the survey studied forty-eight cases in the residential areas in Greater Khartoum, analyzing the collected data that were then summarized in tables and figures.

The findings arrived at from the results presented by the method of assessment were; zero of the case studies were Excellent, 19% were Good, 25% were Pass, and 56% were Weak. The general conclusions relating to the areas of study on the main categories are set out in the conclusion. The conclusions and recommendations for urban housing services, building construction, and community level are set up to be applied in sustainable ecological building in Greater Khartoum.

**Keywords**: Passive solutions. Sustainable Eco Building Principles. Sustainable Assessment Methods. Introduce Assessment method for evaluation of residential buildings in hot-dry climate.

## 3.2. Introduction

This research aimed at investigating the present situation of residential buildings in Greater Khartoum, to evaluate those buildings using sustainable environmental parameters. The problems of residential buildings that were investigated related to problems in the indoor and outdoor environment and services. The research also aimed to find a sustainable assessment method to enable evaluation of residential areas and their services in Greater Khartoum.

The location chosen for the case study was Greater Khartoum, which is classified into three towns: the capital Khartoum, Khartoum North, and Omdurman. The climate is described as hot-dry climate, at latitude 15° 36’ north and longitude 32° 3 east, with an altitude of 380 meters above sea level. The temperature in summer ranges from 40°C to 45°C, which in winter drops to between 14°C and 25°C. The rains range from 100mm to 150 mm. The range of relative humidity is 40% to 60%. Greater Khartoum has been facing floods, desertification and rare earthquakes, and there is a wide variety of natural vegetation in the lands around the River Nile.

### 3.2.1 The research objectives

i. To introduce an assessment method for evaluating residential areas in the four urban classes (High income, medium income, low income, illegal areas) in the private sector in Greater Khartoum by sustainable principles.
ii. To study infrastructure, energy and water utilities, and drainage systems for these neighborhoods.
iii. To study the principles of sustainable design as well as the environmental principles that are suitable for hot-dry climates. To review and analyze the global environmental assessment methods of the buildings. Also, to study the conditions in Greater Khartoum.

iv. To present a methodology for the main categories and sub-issues.
v. To identify the fieldwork tools and procedures, the method of documentation, the method of analysis and the method of presenting the results. The criteria of selecting the case studies.
vi. To make recommendations for sustainable ecological design in the areas of the study for Greater Khartoum. To study the present situation and suggest modifications in materials, water, energy, outdoor environment, site landscape and building form.

## 3.3. The Literature Review

The Passive Solutions and Environmental Principles suitable to hot dry climate.
The aim of this paper is to define the sustainable-eco-building principles in relation to the environment, and at the end we will study all suitable solutions to be applied in sustainable-eco-building and environmental comfort for hot-dry climate. Total points achieved should be 125 points. Sustainable development started in 1992. Sustainable development is defined as: that development which meets the needs of the present without compromising the ability of future generations to meet their own needs. This concept has been explained by Conway (1987). The building design should be economical in: costs of materials, building construction, maintenance, building equipment, energy and water consumption, and there is a need to focus on the fact that the building should be socially connected to the surrounding environment, by providing social services, recognizing human health and safety needs and improving the quality of life. Besides these, the Royal Institute of British Architects (Architect, 2010) considered the minimum key indicators for sustainability design and grouped them according to the structure. The issues recommended for consideration are: land and ecology, community, health, materials, energy and water (Kubba, 2010). Today, new concepts of architectural design allow us to greatly improve the energy performance and to reduce the environmental impact of the materials used in buildings. The Leader in Energy and Environment (LEED) announced six main categories of sustainable design, which are: sustainable site, indoor environmental quality, the energy, the water, the material and innovation. There are many books as well, discussing the issues of sustainable design and

eco-design principles. One such book is by Kubba (2010). Fower (2006) also discussed these issues in his book 'LEED Practices, Certification, and Accreditation Handbook.' Bromberek (2009) also discussed the principles of designing eco resorts, such as site selection and landscape, construction, energy management, water management, waste management, climatic performance. In addition to that (Barrows, 2009) discussed the principles of sustainable design.

Sassi, 2006 and Van, 2009 published a book in 1996 they discussed the principles of ecological design, which are: solutions grow from place, ecological accounting informs design, design with nature, everyone is a designer, and make nature visible. Roaf (2005) reviews the literature on thermal comfort principles and design with reference to the hot-dry climate. The author discusses the basic thermal comfort principles; thermal comfort definition, the heat balance between human and the building, the heat flow, the time lag, human thermal comfort and balance, building thermal behavior, the building material and the importance of ceiling and wall insulation, and the six basic factors of thermal comfort. The passive solution in architectural design is suitable for hot-dry climate, such as urban planning control and spatial control, architectural element and components control, physical aspect control, and controlling the design in indoor environment and outdoor environment and detailing the three building components and discusses the solutions, the hindrances and the risks of solar radiation and high air temperature. The landscaping, implantation of traditional solutions such as passive cooling tower, courtyard system, and controlling building form, ventilation and orientation discussed by Hassan (1995).

Why do we need to introduce a new assessment method for the assessment of eco- building in Greater Khartoum?

The global assessment methods were designed for specific environments, cultures, social and economic problems of those communities, and that is why this research highlights the need of studying the environmental, social, cultural and economic needs for Greater Khartoum.

What are the suitable principles that could be added to the hot-dry climate?

Abdelmoneim (2016) discussed the global sustainable assessment methods and concluded five categories among them: sustainable site, indoor environmental quality, water efficiency, energy efficiency, and material. In addition, the paper went on to add more categories suitable to Greater Khartoum, such as outdoor environment category, building form and environmental design process.

## 3.4 Methodology

**3.4.1** The methodology of this research was intensive study of the available assessment methods, which led to the rationalisation of a new evaluation method for testing the case study according to the nature of residential buildings in Greater Khartoum. This method has been applied to all the levels of urban classes. The methodology consisted of many steps. These included:

1. Review of previous literature in Environmentally Sustainable Development (ESD) and the principles of ecological design was done, along with a review of the passive solutions suitable to the hot-dry climate, and the nature of the case study in the environment. Architectural, spatial and infrastructure was reviewed, besides a review of the historical background of residential areas in Greater Khartoum and the problems faced by them. A general review of the environmental assessment methods; the physical assessment methods and the quantitative and qualitative assessment methods and the sustainable assessment methods which had been adopted in 1992; rationalisation of the new assessment method of the research to evaluate the residential buildings in Greater Khartoum; presenting the study method of assessment and reflecting upon the passive solutions suitable to hot-dry climate along with the principles of sustainable eco buildings.
2. Comparison between four sustainable buildings assessment methods was done during the research and the result was published (Abdelmoneim, 2016).
3. From the comparison, the researcher highlighted the main principles of sustainability, which are sustainable site, indoor environmental quality, material and resources, energy and water efficiency.

Why do we need to add a new sustainable assessment method that is suitable to Greater Khartoum?

The global sustainable building assessment methods were introduced in specific countries to solve the local environmental, cultural, economic and social problems. For instance, Australia introduced management, transportation and land ecology, ESTIDAMA liveable community and integrated design process, and GSAS social and culture. It is evident that all these countries have their own sustainable evaluation methods and have similar as well as different categories for solving their local social, economic, and environmental problems. There was a need to add more categories to solve the local environmental, social, and economic problems. The researcher further added three more categories, which are as follows:

I. Outdoor Environmental Quality: This was integrated for social and environmental impact, because people use the outdoor environment for sitting, welcoming their guests, celebrating, and sometimes sleeping in hot summers. In addition, the researcher added solutions such as the use of canopies, terraces, areas with shade, plants and trees, fountains and the like to cool the air surrounding the buildings.

II. The Building Form: This was included for economic and environmental impact. Studding the building form with solar angle provides more shade to the building and cools the air around the building; and for energy efficiency, studding the windows, vertical and horizontal sunscreens, wind towers, and courtyard system was seen to be more effective.

III. Environmental design process: It was added for two reasons, to control the whole design process including the eight categories, and for educational reason, to educate the architects and engineers and the community about sustainability.

4. The method of assessment used in the study according to the main categories, the sub-issues, and the scale of evaluation was presented, and then the criteria for selecting the case studies, the fieldwork tools, documentation, and analyses, based on interviews with owners and specialists.
5. The fieldwork, including a survey to evaluate 48 case studies in different areas in Greater Khartoum was done, and the data collected was documented, presented and demonstrated in tables and figures and analyzed by computer programmes.
6. The discussion and analyses by the study method of assessment was carried out for all areas of the study, and then the average results for the main categories of the case studies were analyzed and discussed for all areas of study in Khartoum, Khartoum North and Omdurman, followed by the discussion to arrive at the conclusions.

7. General conclusion applicable to residential buildings in Greater Khartoum have been arrived at, and suggestions are provided for areas of further study along with recommendations for future research.

**The study method of assessment**

The study has reviewed environmental assessment methods, including the sustainable assessment methods, identifying five main principles of the study method of assessment. The literature reviewed previously discussed passive solutions suitable to hot-dry climate, also identifying building form and outdoor environment and environmental design process, as well as detailing the main principles of sustainable eco-buildings. To conclude, the main categories of the study method of assessment are sustainable site, indoor environmental quality, outdoor environment, water efficiency, energy efficiency, building materials and building form, and environmental design process. The study method of assessment is explained below.

### 3.4.2. Development of the study method of assessment

The method of assessment was developed using different methods:

1. By carrying out intensive literature review in the area of the study, including the principles of sustainable development, principles of environmental design in urban components, architectural components, spatial aspects, physical aspects, outdoor and indoor environments, as well as studying previous assessment methods and critically analyzing them.
2. Five global assessment methods of sustainable buildings were analyzed; identifying the main categories for the sustainable assessment method, such as: sustainable site, indoor environmental quality, materials, energy efficiency, and water efficiency.
3. After studying the environmental conditions in Greater Khartoum, the research identified three categories that are suitable for the hot-dry climate. These are: building forms, outdoor environmental quality, and environmental design process.
4. Some sub-issues were developed to support the research method of assessment in the field of sustainable buildings (see Appendix-6) to support the method. These issues were: the importance of materials in roof, walls, floors, and décor shown in the

evaluation method; and the use of air conditioning as a negative (-1 point) because it has negative impact on environment.

5. Some solutions were included when reviewing literature on traditional solutions such as the use of courtyard systems, wind towers, domes and vaults effects on absorbing solar radiation.
6. Other solutions were also included based on practical experience, such as the use of vertical and horizontal sunscreens, orientating the building at 45°, and the use of wells and septic tanks in drainage systems.
7. Technological solutions, global and regional, were introduced; these use energy simulation programmes to achieve energy efficiency and use IBM software to develop eco-building designs in computers.
8. Local natural resources in wind energy, solar energy, eco building materials were studied and imposed in the research method of assessment.

### 3.4.3. Scale of evaluation

This Scale was used to evaluate each issue of evaluation of residential buildings in Greater Khartoum.

**Table 3.1: The Scale of evaluation**

| The Mandatory | Meaning | Points given for evaluation |
|---|---|---|
| Positive | Means it's applicable | From 1 to 2 |
| | Positive impact on the environment | 1 |
| | More Positive impact on the environment | 2 |
| negative | Means it's not applicable | 0 |
| | Negative impact to the environment | -1 |
| | Too negative impact to the environment | -2 |

These points were incorporated according to The Predicted Mean Vote (PMV) and scales index.

### 3.4.4. Method of evaluation

The suggested sustainable-eco-building evaluation method for hot-dry climates, such as Greater Khartoum, was applied in this research on the level of Eco Buildings for 48 case studies in Greater Khartoum.

The researcher designed this sustainable-eco-building evaluation method, which is suitable to the local environment in Greater Khartoum. This contains eight main categories: Sustainable site, Indoor Environmental Quality, Building form, Outdoor Environment, materials and resources, drainage system and resources, water supply and drainage system, power supply system, environmental plan process; and the total points that could be scored was 125 points. What makes the difference between this method and the other three systems? The answer is: This method included three other main categories, which are outdoor thermal control, building form, and environmental process as a separate category. Also, this method gave five main evaluation ranges of points, which were: < 40 Weak, (40 - 44 pts) Pass, (45 – 59) Good, (60 - 75 pts) Very Good, (76-125 pts and more) Excellent.

These levels of evaluation were included in reference to British standards of green buildings, BREEAM. BREEAM (2014) uses the same method of evaluation: weak, pass, good, very good, excellent.

The method of assessment that was applied to the 48 samples in different urban classes in Greater Khartoum—the sustainable-eco-buildings assessment method—was designed after a wide-ranging review of the environmental assessment methods and the suitable passive solutions for hot-dry climate. The method combines sustainable main categories, and the passive solutions, taking into account the environmental, spatial, architectural, residential, and technological conditions of the case studies. Table 1 shows the main categories of the method of assessment.

## 3.5. The Discussion of the main categories of the method of assessment

**Table 3.2: Main categories of the assessment method**

| Item | Category | Symbol | No. of points |
|---|---|---|---|
| 1 | Sustainable Site | SS | 13 points |

| | | | |
|---|---|---|---|
| 2 | indoor environmental control | IEQ | 34 points |
| 3 | outdoor thermal control | OTHC | 9 points |
| 4 | Building form | BF | 8 points |
| 5 | materials and Resources | MR | 34 points |
| 6 | water supply and drainage system | (DS&WS) | 16 points |
| 7 | natural power supply | NPS | 15points |
| 8 | environmental design process | (EDP) | 1 point |

**3.5.1. Sustainable site (SS)**

Sustainable site deals with issues outside the building, i.e., the land that is being developed and the surrounding community. Appendix-5 shows the requirement of total points for the sustainable site, which is 12 points, equal to 10% of 125 points. These 12 points come from the main content of the sustainable site category containing sub-issues. These are: site selection (1/12), equivalent weight (0.083); construction system (3/12), equivalent weight (0.25); controlling systems (3/12) equivalent weight (0.25), i.e., parking control, construction activity control and natural water features; alternative transportation (3/12) equivalent weight (0.25), i.e., public transportation access, bicycle storage, and low fuel emission; improved thermal environment (2/12), equivalent weight (0.16), i.e., maximized open space and enhanced landscaping on site; and the study of the heat island effect (1/12), equivalent weight (0.083). For the applied assessment method, each sub-issue scores one or two points according to its importance and positive impact on the environment.

**3.5.2. Indoor environmental quality (IEQ)**

The indoor environmental quality (IEQ) portion deals with materials and systems inside the building that affect the health and comfort of the occupants and construction workers. The indoor environmental quality category of the method of assessment consists of 7 sub- issues. See Appendix-1 and Appendix-2 for details on the assessment method, Appendix- 5 for the requirements and benchmarks for the main categories of the assessment method of the research. The total points which should be achieved were 30/125, which is equivalent to 24%; These 30 points come from the detailed content of indoor environmental quality main issues and sub-issues. The first issue is the building orientation (4/30), equivalent (0.13) which includes applying the building orientation to the North-South direction (1/30) equivalent (0.03), to East - West direction (2/30) equivalent (0.06). The second issue is to control building dimensions by applying surface volume ratios, which should be between 0.12 to 0.16 to avoid exceeding solar radiation on the building (1/30). The third issue is roof thermal control (5/30) equivalent 16.6%, which includes roof thermal insulation (1/30), white colours (1/30), double roof (2/30), and green roof (1/30). The fourth issue is the study of wall thermal control (12/30) equivalent to (0.40) which includes building materials (1), windows (5) equivalent (0.16), shaded devices (4/30) equivalent (0.13), wall paints and colour (1), and green walls (1). The fifth issue is the study of floor thermal control (1/30); choosing the floor finishing material from an eco-floor material manufactured from recycled construction building materials such as concrete, stones, bricks, or ceramics, has long-term durability, and is easy to clean, easy to maintain, durable to pressure, non-slippery, heat and moisture resistant. The recycling content is suitable to most of the residential buildings. The sixth issue is the design of thermal comfort (4/30) equivalent to 0.13, which includes individual thermal comfort (1/30), controlling the natural ventilation, e.g. maximising the windows (1/30), the use of traditional solutions such as wind tower (1/30) and the courtyard system (1/30) that improves the air movement and air temperature in buildings. The seventh issue is supporting these solutions by mechanical means (3/30) equivalent to 0.10, such as using fans, desert coolers or HVAC systems, which helps in controlling the air temperature, air humidity and filtering the air from dust. These solutions vary in different residential areas. However, the use of air-conditioning systems is evaluated as -1 points, because it has a negative impact on the environment. Each sub-issue scores one or two points according to its importance and positive impact on the environment.

### 3.5.3. Outdoor thermal control (OTHC)

The researcher added the outdoor thermal control category. The details of the sub-issues of outdoor thermal control category are as follows: The total points achieved are 9/125 points equivalent to 7%, this number comes from detailed issues and sub-issues of outdoor thermal control category. Each sub-issue scores 1/9 equivalent to 0.11 or 2/9 points equivalent to 0.22, according to their importance and positive impact on the environment. People in Greater Khartoum are aware of the outdoor environment, because the climate is hot and dry. They spend part of their time, especially at nights, in the gardens, which are also utilised during holidays and celebrations. The first issue is to provide shades to the building in the North-South direction (2/9). The second issue is to provide shades in the East-West direction (1/9). The third issue is to provide shades using balconies (1/9). The fourth issue is to enhance landscaping on site using plants and trees that provide shade (1/9). The fifth issue is to build fences to protect the site from dust (1/9). The sixth issue is to build swimming pools (1/9). The seventh issue is installing fountains to change the dry climate into a humid climate (1/9), and also built outdoor terraces (1/9).

### 3.5.4. Building form (BF)

The building forms category was added to the five main categories by the researcher, because it is important to study the relation between solar angle and building form, and then choose the best solution that gives more shade to the building. This helps in cooling the air surrounding the building. Total points to be achieved are 8. Each sub-issue scores 1 point according to its importance and positive impact on the environment.

Although LEED V4 did not add building form as a separate category, Council, U. S. G. B. (2014) suggested: "Provide shade from structures covered by solar panels that produce energy used to offset some non-renewable resource use. Provide shade from architectural devices or structures that have a solar reflectance index SRI of at least 29. Implement a maintenance program that ensures these surfaces are cleaned at least every 2 years to maintain good reflectance". This was added under sustainable site category in LEED V4 and LEED V3. Further, Council, U. S. G. B. (2014) mentioned, "Naturally ventilated buildings must comply with a local standard that is equivalent to ASHRAE Standard 62.1-2007".

There is no specific category or sub-issue dealing with building forms. It is essential to deal with building forms to control building shade and natural ventilation through building orientation. The total points for building form are 8/125 points, equivalent to 6.4 %. These 8 points come from the detailed sub-issues. The research draws details such as linear forms (1/8) equivalent to 0.125, U-shaped forms (1/8), L-shaped forms (1/8), cubic forms (1/8), circular forms (1/8), courtyard systems (1/8), use of vaults (1/8), and use of domes (1/8).

### 3.5.5. Materials and resources (M & R)

The materials and resources category have 13 credits with a total of 34 points. Each sub-issue scores one or two points according to their importance and positive impact on the environment. Materials and resources consist of 13 sub-issues. Total points to be achieved are 34/125 points equivalent to 27%. 34 points come from the detailed issues and sub- issues of building material category. The first issue is the material used in the base like bricks, cement, gravel and stone (6/34), equivalent to 0.176. The second issue is the material used in walls like bricks, stone (9/34), equivalent to 0.264. The third issue is the material used in the roof like cement, bricks and wood (3/34), equivalent to 0.088. The fourth issue is the materials used in finishing such as wood and carpet (5/34), equivalent to 0.147. The fifth issue is the recycling of building materials such as recycled ceramic (2/34), equivalent to 0.058. The sixth issue is wall claddings (1/34), equivalent to 0.029. The seventh issue is indoor décor (3/34), equivalent to 0.088. The eighth issue is construction waste management (1/34), equivalent to 0.029. The ninth issue is calculating the embodied energy (1/34), equivalent 0.029. The tenth issue is life cycle analysis (LCA) (1/34), equivalent to 0.029. The eleventh issue is adopting technologies (1/34), equivalent

0.029. The twelfth issue is applying regional materials like wood and stones (1/34), equivalent 0.029, and the thirteenth issue is low emitting building materials (1/34), equivalent 0.029.

### 3.5.6 Water supply and drainage system (WS&DS)

The water supply and drainage system category have 7 credits. The total points that should be achieved are 16/125 points, equivalent to 12.8%. 16 points come from the detailed issues and sub-issues of water supply and drainage system. See Appendix-1 for details on the sub-issues of water supply and drainage system. Each sub-issue scores one or two points according to their importance and positive impact on the environment.

The first issue is choosing the appropriate technology for the drainage system (5/16), equivalent to 0.312. The second issue is studying the water source (3/16), equivalent to 0.187. The third issue is water efficiency (4/16), equivalent to 0.25. The fourth issue is rainwater container (1/16), equivalent to 0.062. The fifth issue is grey water recycled in the site location (1/16), equivalent to 0.062. The sixth issue is to reduce water usage (1/16), equivalent to 0.062. The seventh issue is to use water sense labelled products (1/16), equivalent 0.062. Most areas of Khartoum in the first and second urban areas use septic tank and well system, because there is no net drainage system available in most of these new urban areas. This system (well and septic tank) is connected to an artesian well, which is usually at a depth of about 50 meters, or until reaching the underground waterbed. This system needs regular cleaning to secure continuous water flow and to avoid clogging. Taking into consideration the ever-present risk of floods during the rainy season, regular maintenance is essential in order to guarantee an efficient system.

### 3.5.7 Power supply system (PS)

The power supply system category has 4 credits, with a total of 15/125 points equivalent to 12%. The total 15 points come from the detailed issues and sub-issues of power system. See Appendix-1 for details on the sub-issues of the power supply system category. Each sub-issue earns one or two points according to their importance and positive impact on the environment.

The first issue is studying the source of energy; an eco-building should provide natural resources such as solar energy and wind energy (6/15), equivalent to 0.4. The second issue is energy efficiency (1/15), equivalent to 0.06. The third issue is studying the applications (5/15), equivalent to 0.33; in Khartoum, sunshine is adequate round the year, and can be utilised as a source of power in all buildings for various activities, lighting, cooking, heating, and cooling; storing this energy in batteries. The fourth issue is adaptive technologies, like photovoltaic technologies, using simulations and energy smart panels (3/15), equivalent to 0.20. All these total 15 points.

### 3.5.8. Environmental design process (EDP)

The main scope of design is to apply the sustainable categories in the whole design process. The term holism has been used to describe the view that a whole system must be considered rather than simply its individual components, as shown in Fig. 1 The Vales have addressed this point in their book “Green Architecture”, suggesting that a building should attempt to address all the principles of green design in a holistic manner (Hide, 2008). Architects should consider the eight categories of the method of assessment of this research to be applied in the design process at all design levels. The total points in this category is one (1/125), equivalent to 0.008.

Pre-building phase: Pre-building phase is the design phase for the primary, developed and final designs, adopting sustainable eco-building categories as its main goals.

Building phase: Building phase is for the construction and system operations. At this level, one should deal with contractors and suppliers, applying appropriate technologies in mechanical systems, construction of waste disposals, and noise control from site.

Post building phase: This level deals with users, after the construction of the building. The building should be maintained regularly in order to guarantee long life and durability. The building should be evaluated using appropriate methods of assessment. These levels are identified after a review of the previous methods in chapter five, such as BREEAM (2014), where< 40 is weak, (40 - 44) pass, (45 – 59) good, (60 - 75 pts) very good, and (76-132 pts or more) excellent.

'The more points you get the higher the building's eco-sustainability will be'.

Figure 3.1 shows the environmental design process.

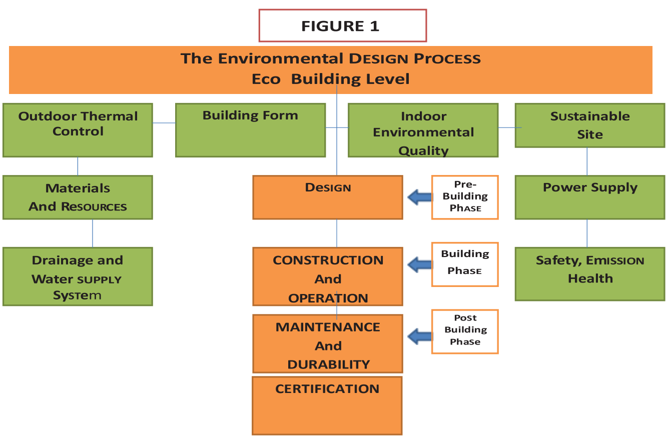



**Figure 3.1: shows the environmental design process on the level of eco-building.**

Source: Abdelmoneim (2019).

## 3.6. Fieldwork

This section explains the procedure adopted for fieldwork in the selected areas of the case studies representing different areas in Greater Khartoum. The duration of the study was from 2015 to 2017. Then the fieldwork results are presented, starting with presentation of the case studies and selected samples and then application of the sustainable-eco-building assessment method of this research (see Apendix-2) to 48 case studies, and then a general summary of information for each case study is given. The results are presented in figures, tables, pie diagrams and photos.

The survey was made in residential areas in Greater Khartoum: Eltaief in Khartoum (8 case studies), Al Sahafa middle (8 case studies), Khartoum Two (5 case studies), and then in the illegal areas in West Sarya (3 case studies); In Kafoori, Khartoum North (5 case studies), Al Shabia (7 case studies); In Omdurman in Al Rouda (5 case studies), and Al Mourada (7 case studies). Thus, the total number of case studies is 48. The method of presentation of these samples was in photos, and short notes and documents about each house were written including information about the name of the owner, the plot size, the built-up area, construction starting date, construction ending date, etc. Then documentation was carried out about the main categories of sustainable design identified in chapter two and discussed in chapter six about the energy used, water, material, indoor environment, outdoor environment, and the infrastructure. This was followed by summarising this information about these specific main categories in tables and figures for each house of the case studies. Figure 2 shows the location of the case studies in Greater Khartoum.

### 3.6.1. Samples' random selection techniques

I. The case studies were divided into four groups according to their date of origin. (See table 2).

II. Group one covered the period from 1992 to 2017 in El Taief in Khartoum, Kafoori in Khartoum North and Al Rouda in Omdurman with plot area variation from 400 m2 to 600 m2.

III. Group two covered the period from 1951 to 1992 in Khartoum with plot areas from 800 m2 to 400 m2.

IV. Group three covered the period of time from 1953 to 1963 in Al Sahafa middle, Al Shabia and Al Mourada.

V. Group four was for the illegal residential areas in West Sarya that have been extending over time. It is an unplanned area.

VI. Samples cover different building types; villas, apartments, and single houses.

VII. They were designed by specialist or consultant architects and built by sub-contractors.

VIII. They were attractive solutions in mass because of their ventilation and orientation and windows design; after that, the researcher went into greater detail by applying the research method of assessment (SEBAM).

IX. Samples are selected for:

a. Studying the indoor environment, windows, ceilings, walls, floors, ventilation and lighting.

b. Studying the outdoor environment, parking, gardens, fountains, swimming pools, fences and terraces.

c. Studying their technical solutions in services such as water supply, waste management, and drainage systems.

d. Studying their building materials, recycled and eco building materials.

### 3.6.2. Samples size

**Table 3.3: Shows the total number of houses in each neighborhood and sample size. Note that the total number of houses was counted from Google Earth, 2019**

| Groups | Town | Name of the Area | Number of the samples | Number of houses in each neighborhood | Sample size | Sample size % |
|---|---|---|---|---|---|---|
| 1.Khartoum | 1.1 Khartoum | El Taief | 8 | 1000 | 0.008 | 0.8% |
| | 1.2 Khartoum | Khartoum 2 | 5 | 1000 | 0.008 | 0.8% |
| | 1.3 Khartoum | Al Sahafa Wasat | 8 | 2000 | 0.004 | 0.4% |
| | 1.4 Khartoum | Illegal, East and West Sarya | 3 | 300 | 0.01 | 1.0% |
| 2.Khartoum | 2.1 | Kafoori | 5 | 500 | 0.01 | 1.0% |

| | | | | | | |
|---|---|---|---|---|---|---|
| North | Khartoum North | | | | | |
| | 2.2 Khartoum North | Al Shabiya | 7 | 1000 | 0.007 | 0.7% |
| 3.Om-Durman | 3.1 Omdurman | Al Rouda | 5 | 500 | 0.01 | 1% |
| | 32 Omdurman | Al Mawrada | 7 | 500 | 0.01 | 1% |
| | | | 48 | 6800 sample house | 0.007 | 0.7 % |

Source: Google Earth Satellite image, 2019

Sample size = number of selected samples /Total number of houses

= 48 / 6800

=0.7 %

This sample size does not meet the 95%. Confidence level statistically; the researcher needs more than 200 samples to achieve that. This sample size is in the limitations point 4.2.1.

### 3.6.4. The limitations of sample size

The limitations of sample size because of the following reasons:

a. The samples of this study are different types of residential buildings including houses, villas and apartments from different areas in Greater Khartoum including the first class, second, third and illegal areas.
b. The researcher starts by the fact that large sample size gives more accurate and meaningful results with no hesitation and gives more power to the study.
c. However, in this the research there are some reasons cause the limitations of sample size:
    i. The economic reason, the more sample size you take in the survey it will cost money in transportation and in the analysis.
    ii. Conflict reason in the illegal areas, it is difficult to enter these areas alone because it’s not safe.

iii. The same result for the same group because of the limited solutions for sustainable-eco-buildings assessment method (SEBAM), the researcher notice that buildings in the first group got results between (40 to 50), while buildings in the third group got results between (20 to 30) and illegal areas got results between (16 to 17).

   On the other hand, Scott, 2016 stated that “the mean value of a continuous outcome variable in one group differs significantly from that in another group from that in another group”. (Scott, 2016).

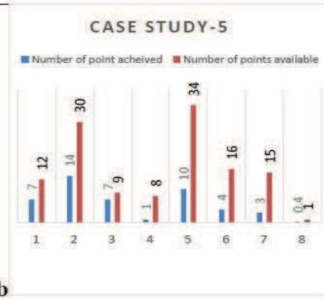
iv. The logistical reason, (eg, large surveys are usually conducted by teams, not individuals).

### 3.6.5. Samples from the case studied

This house was constructed during the period 2002-2007. Abdall Mohammed Mualla designed the house using glass and aluminium mixed with the traditional Islamic style such as; Mashrabia and arches. The architect used the linear form and the building is oriented towards the North-South direction. The architect has used a solar heating system. There are many elements that represent shade; there are balconies oriented to the North- direction and to the East-South direction. Ventilation is maintained through large windows directed towards the North-South direction, while other small windows are oriented towards the East-West direction. The outdoor environment is well designed and shows a large garden, in addition to high fences, shaded and isolated car parking, and large terraces (see Figure 6.7) shows sample 5.

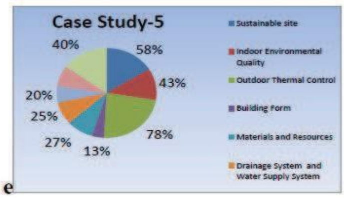
| Main categories | Number of point acheived | Number of points available | |
|---|---|---|---|
| Sustainable site | 7 | 12 | 58 % |
| Indoor Environmental Quality | 14 | 30 | 43 % |
| Outdoor Thermal Control | 7 | 9 | 78 % |
| Building Form | 1 | 8 | 13% |
| Materials and Resources | 10 | 34 | 29 % |
| Water Supply System | 4 | 16 | 25 % |
| Power Supply | 3 | 15 | 20% |
| Environmental Sustainable Design Process | 0.4 | 1 | 40% |
| Total | 48% | 125 | Good |

a.




b

PL.f: Solar heating system




e

Pl c: The East elevation

Pl d: The North elevation

**Figure 3.2: Sample 5, plot 910, block 22, El Taief. Table (a), Figure (b), Pl (c), Pl (d), Pl. (f) and Pie (e) show the results of sample 5.**

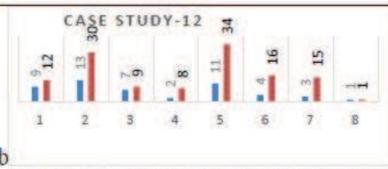
### 3.6.6. Sample two from the case studied

*Sample No. (12): Geraif West, Plot No: 365/1, Block No: 5,*

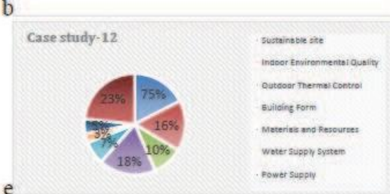
This house was designed by the architect Dr. Othman El Kheir and built-in Gerif West neighborhood in Khartoum during 1996-1999. It attempts to demonstrate several features significant to the designer. In this case, the keywords were environment, traditions and modernity. Great consideration has been given to orientation and shading. Natural ventilation is made easier by the intrinsically narrow plan and the open multi-level interior. A wind catcher further accentuates this, along with underground brick ducts for supplying cool filtered air. Small high-level openings siphon the hot air and enhance conventional currents. The incorporation of plants in the interior is combined with a water sprinkling system for irrigation and climate modification. Solar energy provides the back-up supply for lighting and low-demand appliances. The structure is a composite RC frame and brick load-bearing walls system. The frame constitutes a stiff core holding brick vaults and combating the resulting lateral forces. The area framed by the RC skeleton recedes upwards from the ground level to the first level, leaving the third level for load- bearing walls. Perpendicular vaults acting as buttresses frame openings and casting shadows further assist this (see Figure 6.15).

| | Main Categories | No. of points achieved | No. of points available | No of credit |
|---|---|---|---|---|
| 1 | Sustainable site | 9 | 12 | 75 % |
| 2 | Indoor environmental quality | 13 | 30 | 40 % |
| 3 | Outdoor thermal control | 7 | 9 | 42% |
| 4 | Building form | 2 | 8 | 25% |
| 5 | Materials and resources | 11 | 34 | 32 % |
| 6 | b.Water supply system | 4 | 16 | 12.5% |
| 7 | Power supply | 3 | 15 | 20% |
| 8 | Environmental design process | 1 | 1 | 100% |
| 9 | | 50% | 125 | Good |

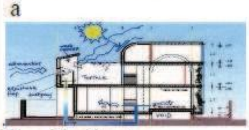
a




b




e



PL. a:The Section

PL.c: East elevation

PL.d :The ground floor plan

**Figure 3.3: Sample 12, plot (365/1), block (5), Geraif West. Table (a), Figure (b), Pl (c) and (d) and Pie (e) shows the results of sample 12.**

## 3.7. The Findings

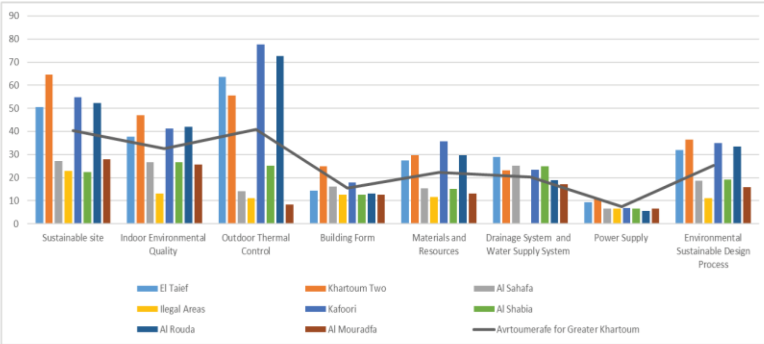



**Figure 3.4: The average results for all categories on the selected areas of the study in Greater Khartoum. Source: (Abdelmoneim, H., 2019)**

**Table 3.4. Conclusions of the discussions of the average results for all categories on the selected areas of the study in Greater Khartoum.**

| Thae Main Category | El Taief | Khartoum 2 | Al Sahafa | Ilegal Areas | Kafoori | Al Shabia | Al Rouda | Al Mouradfa | Average for Greater Khartoum | Evaluation |
|---|---|---|---|---|---|---|---|---|---|---|
| Sustainable site | 51 | 64.6 | 27 | 23 | 55 | 22 | 52 | 28 | 40 | Pass |
| Indoor Environmental Quality | 38 | 47.8 | 27 | 13 | 41 | 27 | 42 | 26 | 33 | Pass |
| Outdoor Thermal Control | 64 | 55.6 | 14 | 11 | 78 | 25 | 73 | 8 | 41 | Pass |
| Building Form | 14 | 24.8 | 16 | 13 | 18 | 13 | 13 | 13 | 15 | Weak |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Materials and Resources | 28 | 29.6 | 15 | 12 | 36 | 15 | 30 | 13 | 22 | Weak |
| Drainage System and Water Supply System | 29 | 23.14 | 25 | 0 | 23 | 25 | 19 | 17 | 20 | Weak |
| Power Supply | 9 | 10.584 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | Weak |
| Environmental Sustainable Design Process | 32 | 36 | 19 | 11 | 35 | 19 | 33 | 16 | 25 | Weak |

Source: (Abdelmoneim, H., 2019)

## 3.8. Conclusion

- The research concluded that the sustainable site in most residential areas in Greater Khartoum has a good accessibility level with a score of 35%, attributing to the proximity of plot to a public transportation axis. The third group, for this parameter, showed poor accessibility and revealed a score of 20%, attributing the high distance of the plot from the main road. This long distance is because of the selection of a site in accordance with the land distribution or allotment from the Ministry of Housing and Urban Planning.
- The research concluded that residential buildings have good control to parking covered by the shed, noise prevention, and waste management with a score of 65% for the first group. However, for the third group, the research inferred weak control in parking, noise and waste prevention with a score of 40%.
- In addition, large open spaces were found for the first group due to the moderate plot sizes ranging between 400 and 600 sq.m, and thus the group received a score of 60% in the data analysis. On the other hand, the research found limited plot area in the third group, size (250-300 sq.m.) with a score of 40%, according to distribution land standards for urban classes from Ministry of Urban planning.

- Heat island effect has been inferred to be significantly low in all the study samples, and thus disclosed a score of 20%. Minimum solutions found in solving the heat island effect.
- The indoor environmental quality; most of the residential buildings largely evidenced has good solutions, including roof insulation, building dimensions, windows design, vertical and horizontal sunscreens, and natural ventilation, use of fans and desert coolers, and good orientations. With a score of 33%, however, the groups also evidenced weak solutions, which seen in the use of techniques such as wind towers, courtyard systems, and double roofs. It concluded that some groups did not demonstrate the use of green walls, green roofs, thermal comfort control, lighting control HVAC systems and occupancy based blinds or curtains.
- In the outdoor environment shows good applicable solutions such as shades, terraces, canopies, balconies and vegetation and landscape, and accordingly, received a score of 67%, attributing to the large plot sizes ranging between 400 and 600 sq.m. On the other hand, weak solutions were provided in the analysis, which revealed a score of 14.5%, because of the small plot sizes ranging between 250 and 300 sq.m.
- As regards to the environmental design process, the study revealed weak points for all areas of the study in Greater Khartoum; were found, and the corresponding score was 33% as an average result.
- The research concluded that most of the buildings in the areas of the study showed the use of linear forms with a score of (60%), then cubic forms (19%) and the courtyard systems. There were no alternative solutions to SEBAM like vaults, domes (Only case study No. 9), L-shaped forms revealed a score of (11%) (Only case studies No. 8 and No. 47) and U-shaped forms. The contributing factors to these results could be the high price of plots and the need to maximize the built-up area.
- As regards building construction; the study revealed, the use of applicable solutions, such as concrete skeleton for residential buildings in Greater Khartoum, which received a score of 57%. Similarly, load-bearing systems revealed a score of 44%, and mud bricks in illegal areas revealed a score of 100% because these

solutions necessarily met the residents' needs and were economical. The research found problems in the ceiling and poor insulations in the third group.

- The use of materials in construction, it was concluded that the buildings had concrete ceilings (57%), bricks or hollow blocks in walls, and ceramic (67%) or marbles (16.4 %) on floors. Then, wood and coated corrugated sheets ceilings (32%), bricks in walls, and recycled ceramic on floors (12%). Also, sand, gravel and clay blocks were observed in the illegal areas as owners and professionals prefer to use materials available in the local environment.
- It concluded that applicable solutions such as waste management, roof clay tiles, wall cladding, glass, aluminium, and wood were not evident across the study samples. The reason for the limited or negligible use of wood, roof clay tiles and cladding could be attributed to their high costs and unavailability in the local market. Moreover, limited solutions were evident in the use of recycled materials.
- The research concluded that all case studies the water was sourced from the National Grid. The research specifically shows unsuitable solutions in the use of biological treatment, rainwater containers, water metering system, water recycling, and water efficient products because residents present limited affordability in using such solutions.
- The research concluded that all amongst the case study sample, they used septic tanks and wells, and accordingly received a score of 75% in the drainage systems. These drainage provisions, however, could contaminate the underground water. The analysis for Khartoum 2 neighborhood revealed the use of a proper drainage network and thus received a 100% score in the sewage system. However, in Omdurman, some buildings still evidenced the use of pit latrine, and, as such received a score of 12.5%; and in illegal housing areas, sand and gravel filters were extensively used, with a score of 100%.
- The research revealed that as all case study samples in Greater Khartoum used energy from the National Grid and thus received a score of 100%. However, few alternative solutions as regards SEBAM are evident in the use of solar energy, energy heating system, outdoor lighting and solar heating. Only the case study No. 5 used solar heating and case study No. 9 used solar PV cells. The research, furthermore, shows the use of unsuitable solutions in wind energy and solar

boiling because the population does not prefer employing such expensive solutions.

## 3.9. Recommendations

***Recommendations regarding the proposed evaluation method***

- The research recommends that the proposed evaluation method could be reviewed and developed by the industry academics, professionals, with their approval could be implemented by the Ministry of Housing and Urban Planning. Consequently, the advantages and benefits from the application of this research method of assessment could be apparent the application of all recommended solutions as suggested in the SEBAM studies to the 48 samples (See Appendix-1 and Appendix-5). Moreover, with the leveraging of this assessment method, as proposed in the study, the architectural field can immensely benefit and sustainable-Ecological-building, healthy, economical houses could be constructed.
- The research recommends that architects, professional could include recommendations for a larger survey on developing the building materials, energy efficiency, water efficiency, building form, site, indoor and outdoor environment.

***Recommendations to apply sustainable-Ecological-buildings in Greater Khartoum***

- The accessibility to all plot areas should be near to a public transportation axis.
- The site should have protocols, implementation of construction activity control, noise prevention, and waste management.
- The site should have good landscape management, consequently solar lighting control.
- Heat island effect should be necessarily studied through strategic positioning of plant trees, moreover, use of light colors.
- The natural ventilation through windows, the use of horizontal, consequently vertical sunscreens should be provided.

- The mechanical means such as desert coolers and fans could be used to improve the thermal comfort inside the building.
- The building should be oriented towards the East-West direction in the hot-dry climate.
- The use of wind towers, the use of courtyard systems, moreover the implementation of light color paints on ceilings and walls could be applied.
- Solutions such as double roofs, green roofs, green walls, floor thermal control, design thermal comfort, consequently lighting control could be added to Ecological buildings.
- Open spaces at the house unit level should be provided with controlling shades, cantilever, moreover canopies.
- Fences in the outdoor environment could be built to protect the building from waste and for safety.
- Water features humidify could be built to humid the air surrounding the building.
- Trees and vegetation cover should be maintained to improve the air from dry to humid in all areas of the study.
- The building form like the linear and cubic forms, vaults, and domes is recommended.
- L-shaped and U-shaped forms could be applied in sustainable-Ecological-buildings to provide more shades to the building, accordingly, cools the air through the building and improves ventilation.
- The environmental design process could be applied in the three design phases as an educational value.
- Insulation in the roof, walls should be used.
- Construction materials for the buildings should be provided from the local environment.
- Recycled materials could be used whenever possible, especially for the outdoor area. Ecological carpets and suspended ceilings are recommended in the indoor environment.
- Water efficiency should be increased by adopting standards of The World Health Organization (WHO).

- The research is recommended adopting a distribution network for sewerage systems for all residential areas.
- The research recommended maintaining and minimizing the use of septic tanks and wells, as they are contamination threats to underground water.
- Accordingly, the application of solutions such as recycling of grey water, and rainwater collector is recommended in sustainable Ecological building.
- Natural resources for energy such as solar energy system could be applied in different applications like solar heating, solar cooking, solar photovoltaic technology.
- The research strongly recommended adding educational value to increase the knowledge of the community and teach the students, architects, designers, and people about sustainable- Ecological- building through lectures, workshops, conferences and courses corresponding to its main categories.

### 3.10. Acknowledgements

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# CHAPTER FOUR

# BENCHMARKING CASE STUDY IN GREATER KHARTOUM

# Benchmarking Case Study, Applying Sustainable-Eco-Building Assessment Method (SEBAM) in Greater Khartoum, Comparing with Global Systems

## 4.1. Abstract

This sample was taken as benchmarking in (Abdelmoneim, H., 2019) which has got the higher points comparing with all the other samples studied in this research, is chosen for global assessment approach an excellent solution for the sustainable-eco-building assessment method (SEBAM).

This study aims is to present and analyses a benchmarking case study for sustainable eco-buildings in Greater Khartoum is the capital of Sudan, one of The greatest countries in north Africa.

The methodology is applying global assessment method to this case study, which is LEED, BREEAM, AGBC, ESTIDAMA and GSAS then compare the result with the local system came up of (Abdelmoneim, H., 2019), sustainable eco-building assessment method to evaluate residential buildings (SEBAM) to justify the results. The comparison is done in this research in the main categories and results. The outcomes show differences rather than similarities this will be discussed in the paper and come up by conclusion and recommendations.

*Keywords*: sustainable eco-building assessment method (SEBAM), LEED, BREEAM, AGBC, GSAS, ESTEDAMA, SEBAM.

## 4.2. Introduction

The location of the case study is in South East Khartoum city, the climate is a hot dry climate. This house was built in Geraif West Neighborhood in Khartoum city; it was built in the late nineties. It attempted to demonstrate several features of significance to the designer. See figure 1 showing the location of the case study at Khartoum the capital of Sudan.


**Fig. 4.1. The political map, 2020 (Washington DC, 2020)**

- **Climatic Conditions**

Khartoum's climate is characterized by its hot and dry nature. In addition, is characterized by intensive heat resulting from the blowing of dust storms (i.e., Haboobs) from the South East. This phenomenon, in fact, produces one of the most striking weather features experienced in the area.

- **Temperature**

There are three well-marked seasons in the year. The cooler winter season covers the period mid-November to March, and the summer season covers the period April to October. The temperature range in winter is from a high of 29˚C to a low of 17˚C, and in summer, the temperature range is from 40˚C to 28˚C.

- **Rainfall**

In winter, the precipitation is effectively zero. The rainy season starts from July until the end of August with average rainfall in the capital region ranging from North to South at 100 mm to 200 mm. As per reports, Khartoum's highest annual rainfall was 420 mm in 1988. The chain of rain decreases markedly after mid-September.

- **Humidity**

The range of relative humidity in summer is 87% to 36%, in winter it is 30%, and in autumn, it is 40%.

- **Wind**

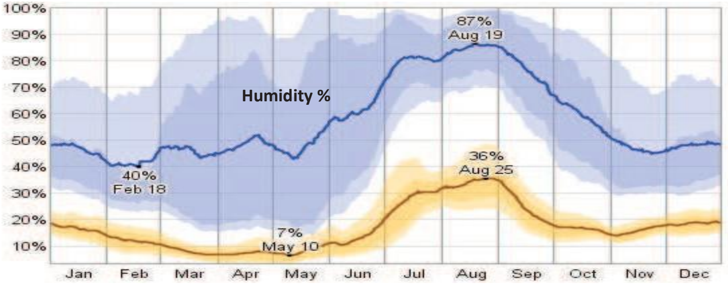
In summer, the wind direction is South East and South West. In winter, the wind direction is North East and North West. In June, during the summer season, the growing instability of weather can cause dust storms (also called Haboobs). However, robust Haboobs can occur in almost any month of the year. See

- **Topography**

Khartoum land slopes gently at both flanks of the River Nile down towards the center (Jebel Marra, and Jebel Meidoob). Fine silt is deposited along the beds of the streams, and rich clays are generally abundant in the area. When we design a neighborhood study of the topography, and the contour lines as well as the sea level features, it is very important to avoid flood areas and valleys.

- **Vegetation**

The area is composed of land divided into three towns: Khartoum, Khartoum North, and Omdurman, and is 380 meters above sea level. The White Nile from the South and the Blue Nile from South East unite in Khartoum and provide a good source of water to the land. Another source is the rainwater in autumn, which is about 100 mm. The distribution of the vegetation in Greater Khartoum is affected by the soil, the water sources, and the geology. There is little binding vegetation here, but going further south, the vegetation gradually changes from desert to semi-desert to Savannah with long grasses, and large trees near the river Nile.



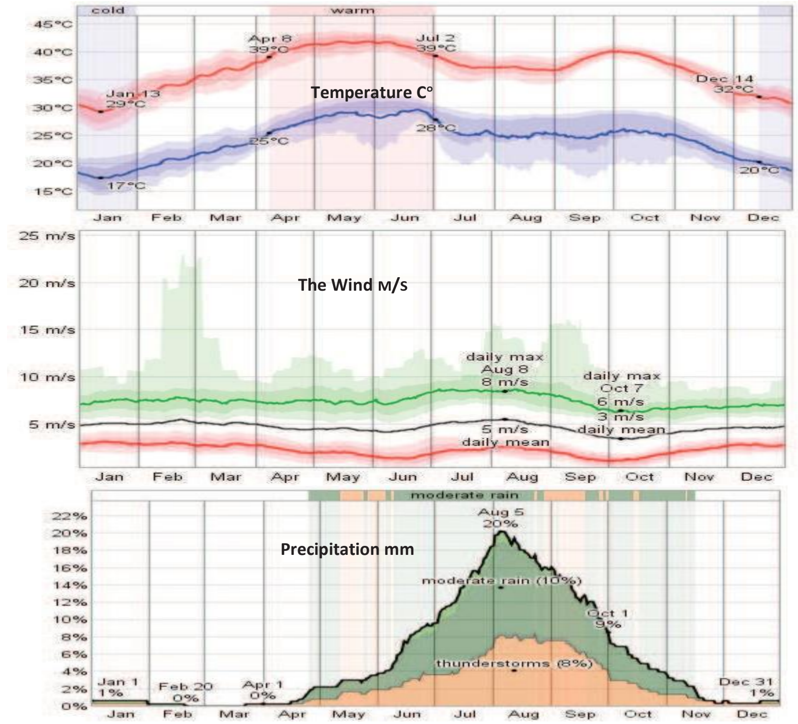



**Figure 4.2. Precipitation of metrological data in Greater Khartoum (www.weatherspeak.com, 2020)**

## 4.3. Literature review

Hassan Fathy conducted several works about sustainable design in the thirties and forties, and these efforts were later acknowledged in 1992. Since then an inclined trend was observed in the global community towards studying the relationship between building design and the surrounding environment. Specifically, a building should present a balanced and congruency with the surrounding environment in terms of social, economic and environmental aspects to achieve the sustainability goals and comfort for a human being. (Ibrahim, 1987).

The main principles of sustainable design, as presented in Table 1, are considered as the minimum standard to be followed for sustainable design.

The Leader in Energy and Environment (LEED, 2020) announced six main categories of sustainable design, which are the sustainable site, indoor environmental quality, energy, water, material, and innovation. (GSAS, 2020) focuses on urban connectivity, Site, Energy, Water, Materials, Outdoor environment, Culture & economic value. (BREEAM, 2020) BREEAM focuses on land use and land ecology, energy, water, material, health and wellbeing, transport, material, waste pollution and innovation. Royal Institute of British Architects' (RIBA), 2010) recommended land and ecology, community, health, materials, energy, and water as essential to sustainable design. Kubba (2010) and Fower (2006) Discussed these issues in "The Leader in Energy and Environment "LEED Practices.

Bromberek, (2009) discussed the principles of designing eco-resorts. The principles of eco-resort meet with the principles of the eco neighborhood in site selection, landscaping, construction, energy management, water management, waste management and climatic performance. Barrows, (2009) presented the complete guidelines to green building. The guidelines for green buildings include constructions, planning phase, building materials, water, energy, lighting, roofs, floors, walls, windows, indoor air quality, outdoor, shades, green fencing, green lighting, green decking and green pool. Sassi, (2006) and Van, (2009) published a book in 1996, the title of its second part is "The Ecological Design Process". They discussed the principles of ecological design, which are: solutions grow from the place, ecological accounting informs design, design with nature, everyone is a designer, and make nature visible. (Su, 2016) published a paper in IECC, International conference in Environmental and Climatic Change Comparison of field measurement CFD simulation is implemented to recreate thermal conditions of two buildings in both seasons. To evaluate the field measurement results in natural ventilation effect at the atrium, with the air velocity. (Alwetaishi, 2018) published a paper in IECC.

International conference in Environmental and Climatic Change in France. The paper concentrated in the passive solutions and stated that it is one way to ensure low building energy, the researcher applied Thermal Analysis Simulation (TAS) will be utilized which is powered by Environmental Design process. (UN-HABITAT, 2016) the report presented at the 3rd International Conference for housing and sustainable planning. The report covered most of the points of UN sustainable development goals about Sudan. (Zuhal, November 2018) published paper in International conference and the built environment in London Zuhal discussed the low coast housing in Greater Khartoum, in New Deims, El Shabyia, Al Iskan the Project, Elthora hara and compare in size, area, design type , and house type. (Zuhal, 2014) published paper in The Opportunities and Challenges for Sustainabilty in Old Neighbourhoods)- A Case Study of Aburoof

Neighbourhood in Sudan showing the opportunities of the sustainable community. Khalil (2014) published paper about PhD research in sustainable tools in Khartoum Projects. Khalil (2014) used LEED-ND, BREEAM, and CASBEE systems for his study and discussed that his study reflects the social and economic needs of Greater Khartoum. He furthermore suggested to include energy, natural system, materials, society, services, business and creative design in evaluating sustainable projects in Greater Khartoum. Abdelmoneim, H., (2016) published a paper in JSD about comparison in four global systems showing and analysing the main categories of the global systems with their weighings. In addition Abdelmoneim, H., (2016) Published paper in JSD about the local sustainable-eco-building SEBAM come out of PhD research to be applied in Greater Khartoum in Sudan.

***Definition of Eco Buildings***

Specifically, eco-building concentrates on the passive solutions, which uses natural solutions in design without mechanical means, such as ventilation, building orientation, natural light, improve air movement, use of local building material and the use of natural resources in energy, water, and material. All these issues will be discussed in this chapter. The meaning of eco-homes can be derived from the term ‘eco’, which finds its origin in the Greek root ‘Oikos’, meaning ‘household’. The Greek root has two meanings: the sense of ‘ecological’ relationships between organisms in nature, and ‘economics’ relationships with the use of ‘resources. Additionally, the idea also pertains to the use of new knowledge, materials and renewable technologies to create buildings and refers to the new vernacular aimed at minimizing the adverse environmental impacts of the buildings (Hyde, 2008). Diverse environmental impacts can be measured using new methodologies for counting the environmental costs of buildings, the first eco House in the UK.

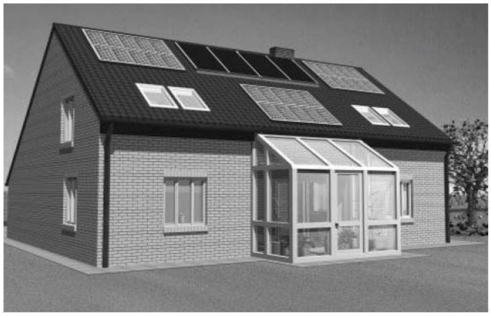


**Figure 4.3. (Roaf, 2013). The first eco -house in the UK in 2013 showing the use of passive solutions with the solar energy system**

### 4.3.1. Objectives

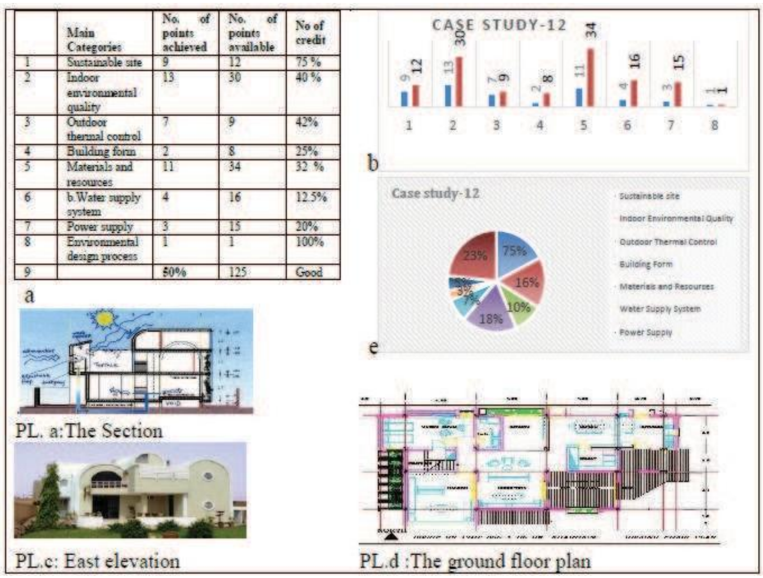
1. To find Benchmarking case study in sustainable-eco-building in Greater Khartoum.
2. To compare global solutions for sustainable eco- buildings with (SEBAM) in Greater Khartoum was discussed and published (Abdelmoneim, H.2020).
3. To find out the applicable solutions from the global systems (Abdelmoneim, H., 2019).
4. To find out an applicable solution from the local system applied the SEBAM (Abdelmoneim, H., 2019) and (Abdelmoneim, H. , 2020) contain eight main categories see Table 1, Figure 1.

### 4.3.2. Introduction to the case study

In this case, the keywords were environment, traditions and modernity. Great consideration was hence given to orientation and shading and to the passive solution.

The location of the case study is in Khartoum middle, Gerif west. The plot area is 400 m2, the house has a square plan, in the ground floor the main reception, kitchen, office room, in the first floor the bedrooms and family hall. The climate is detailed in 1.1 page 2.

Natural ventilation was made easier by the intrinsically narrow plan and the open multi-level interior. A windcatcher further accentuated this and underground brick ducts for supplying cool filtered air. Small high-level openings siphoned the hot air and enhanced convectional currents. The incorporation of plants in the interior was combined with a water sprinkling system for irrigation and climate modification. Solar energy provided the back-up supply for lighting and low-demand appliances as well as Water: It is from the National Grid; water efficiency is 70%; which indicates a shortage of water supply. Drainage system: septic tank and well. Energy: supplied from the National Grid, energy is generated through hydropower. The structure is a composite reinforcement concrete. Frame and brick load-bearing walls system. The frame constitutes a stiff core holding brick vaults and combating the resulting lateral forces. The area framed by the RC skeleton receded upwards from the ground level to the first level, leaving the third level for loadbearing walls. Perpendicular vaults acting as buttresses framing openings and casting shadows further assist this. The interior is softly rendered and made very simple and open. It accommodates artwork, feature panels and sometimes purposely designed furniture.



| | Main Categories | No. of points achieved | No. of points available | No of credit |
|---|---|---|---|---|
| 1 | Sustainable site | 9 | 12 | 75 % |
| 2 | Indoor environmental quality | 13 | 30 | 40 % |
| 3 | Outdoor thermal control | 7 | 9 | 42% |
| 4 | Building form | 2 | 8 | 25% |
| 5 | Materials and resources | 11 | 34 | 32 % |
| 6 | b.Water supply system | 4 | 16 | 12.5% |
| 7 | Power supply | 3 | 15 | 20% |
| 8 | Environmental design process | 1 | 1 | 100% |
| 9 | | 50% | 125 | Good |



**Figure 4.4: Benchmarking case study from Greater Khartoum Source: (Abdelmoneim, H., 2019)**

## 4.4. The Methodology

The methodology is applying global assessment method to this case study, which is LEED, BREEAM, AGBC, ESTIDAMA and GSAS then comparing the results with the local system sustainable-eco-building assessment method to evaluate residential buildings (SEBAM) to justify the results.

The global systems were well known and detailed in (Abdelmoneim, H., 2016) and SEBAM were detailed in (Abdelmoneim, H., 2020).

## 4.5. Results and findings

1. *The local system: Sustainable-Eco-Building Assessment Method (SEBAM)*

**Table 4.1: The Local system SEBAM, applied to the case study, results**

| | Main Categories | No. of points achieved | No. of points available | No of credit |
|---|---|---|---|---|
| 1 | Sustainable site | 9 | 12 | 75 % |
| 2 | Indoor environmental quality | 13 | 30 | 40 % |
| 3 | Outdoor thermal control | 7 | 9 | 42% |
| 4 | Building form | 2 | 8 | 25% |
| 5 | Materials and resources | 11 | 34 | 32 % |
| 6 | b.Water supply system | 4 | 16 | 12.5% |
| 7 | Power supply | 3 | 15 | 20% |
| 8 | Environmental design process | 1 | 1 | 100% |
| 9 | Total | 50% | 125 | Good |

Source: The global systems were well known and detailed in (Abdelmoneim, H., 2016) and SEBAM were detailed in (Abdelmoneim, H., 2020).

*2. Green Star Rating System IN AUSTRALIA*

**Table 4.2. The result by the Green Star Rating System.**

| Credit | Number of points Achieved | Number of points available | % |
|---|---|---|---|
| Management | 7 | 14 | 50% |
| Indoor environment quality | 17 | 17 | 100% |
| Energy | 7 | 22 | 31% |
| Transport | 8 | 10 | 80% |
| Water | 8 | 12 | 66.66% |
| Materials | 4 | 14 | 28.5% |
| Land use and ecology | 3 | 6 | 50% |
| Emissions | 1 | 5 | 20% |
| Innovation | 3 | 10 | 30% |
| Total | 50 points<br>4 star | 110 | |

Source: Designed by the researcher.

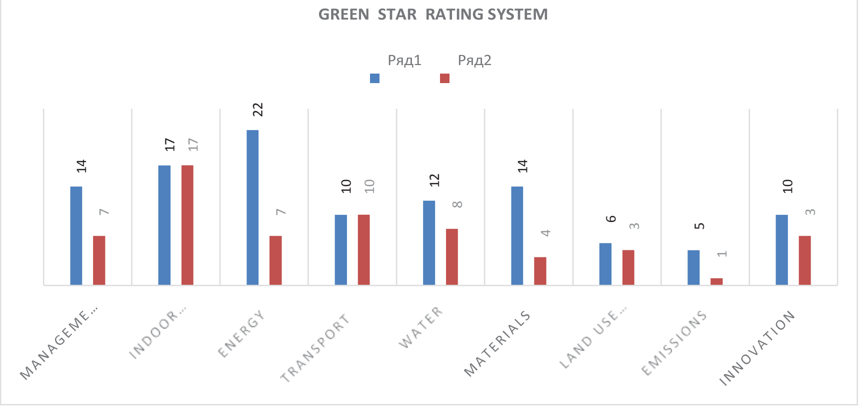



**Fig. 4.5: Shows the Green Star Rating System results for one case study, source: Adapted by the researcher.**

*3. The BREEAM rating system in the UK*

**Table 4.3. The result by BREEAM rating system in the UK**

| Issue name | Achieved | Credit available | % |
|---|---|---|---|
| Land use and land ecology | 2 | 10 | 20% |
| Energy | 19 | 31 | 61% |
| Water | 4 | 9 | 44.4% |
| Material | 6 | 14 | 42.8% |
| Health and wellbeing | 4 | 22 | 18.1% |
| Transport | 2 | 12 | 16.6% |
| Materials | 8 | 14 | 57.1% |
| Waste | 6 | 9 | 66.66% |
| pollution | 2 | 13 | 15.3% |
| Innovation | 3 | 10 | 30% |
| Total | 56 (very good) | 144 | |

Source: Adapted by the researcher.

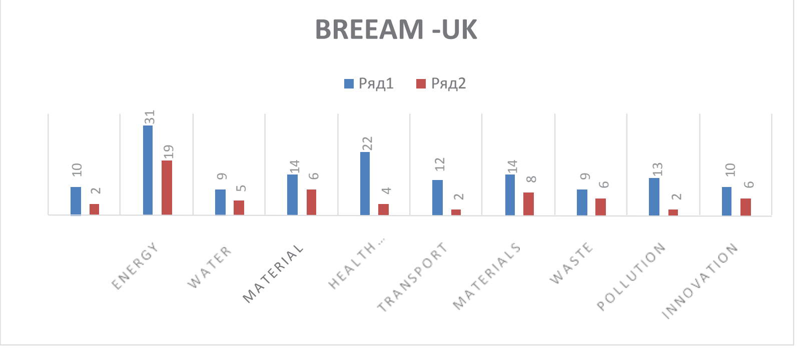



**Fig. 4.6: Shows the results of the BREEAM applied for one case study, source: Adapted by the researcher.**

*4. The leader in energy and environment development (LEED)*

**Table 4.4. The result by LEED V4 rating system**

| Category | Point achieved | Point available | % |
|---|---|---|---|
| Location and Transportation | 10 | 15 | 66% |
| Sustainable site | 6 | 10 | 62% |
| Water efficiency | 10 | 12 | 83% |
| Energy & atmosphere | 12 | 38 | 31.3% |
| Material & resources | 3 | 8 | 37% |
| Indoor environment | 4 | 17 | 23% |
| innovation | 4 | 6 | 66% |
| Regional priority | 2 | 4 | 50% |
| Total | 51 % (silver) | 110 | |

Source: Adapted by the researcher.

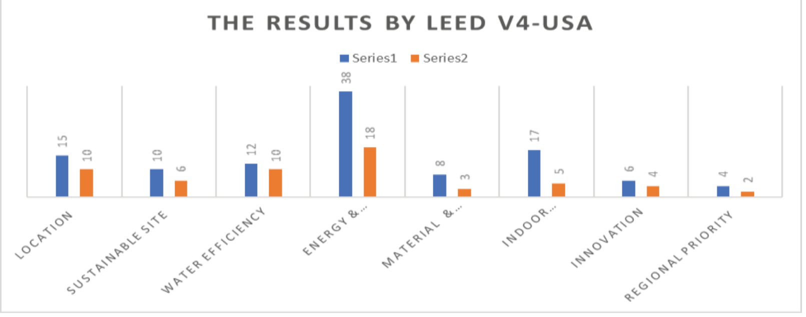



**Fig. 4.7: Shows the results LEED V4 applied for one case study, source: Adapted by the researcher.**

*5. Estidama building rating system*

**Table 4.5. The result by ESTIDAMA building rating system**

| Credit | Achieved points | Maximum credit points available | % |
|---|---|---|---|
| Integrated development process | 5 | 13 | 38% |
| Natural system | 2 | 12 | 16.6% |
| Livable building: outdoors | 8 | 14 | 57.14% |
| Livable Building: indoor | 17 | 23 | 73.9% |
| Precious water | 8 | 43 | 18.6% |
| Resourceful energy | 9 | 44 | 20.4% |
| material | 14 | 28 | 50% |
| Innovation practice | 2 | 3 | 66.6% |
| Total | 65 ( 2 pearl ) | 180 | |

Source: Adapted by the researcher.

*6. Global sustainability assessment system (GSAS)*

**Fig. 4.8: Shows the results of ESTIDAMA applied for one case study, source: Adapted by the researcher.**

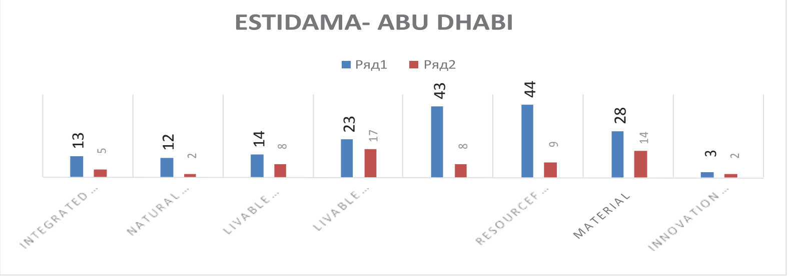



**Table 4.6. The result by GSAS**

| | Category | Achieved weight | Weighing available | % |
|---|---|---|---|---|
| UC | Urban connectivity | 7 | 7 | 100% |
| S | Site | 2.74 | 15 | 18% |

| | | | | |
|---|---|---|---|---|
| E | Energy | 6.87 | 24 | 28.6 |
| W | Water | 6 | 16 | 37.5 |
| M | Materials | 5.7 | 12 | 47.5 |
| IE | Outdoor environment | 4.03 | 16 | 25% |
| CE | Culture & economic value | 3.12 | 7 | 44.5% |
| MO | Management and operation | 1.2 | 8 | 15% |
| | Total | 36.66<br>2 stars | 105 | |

Source: Adapted by the researcher.

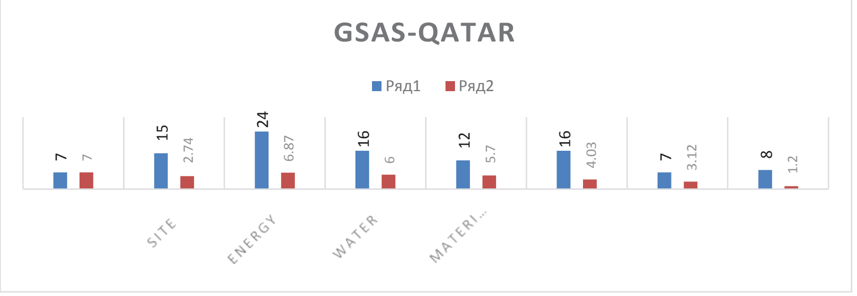



**Fig. 4.9: Shows the results of GSAS applied for one case study, source: Adapted by the researcher.**

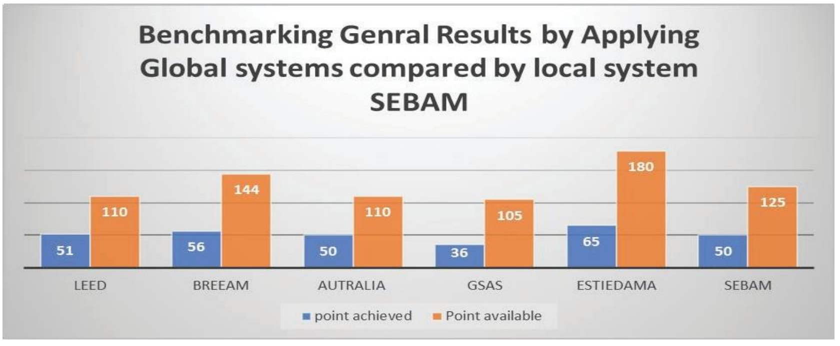



**Fig. 4.10: Benchmarking general results by applying global systems compared by local system SEBAM**

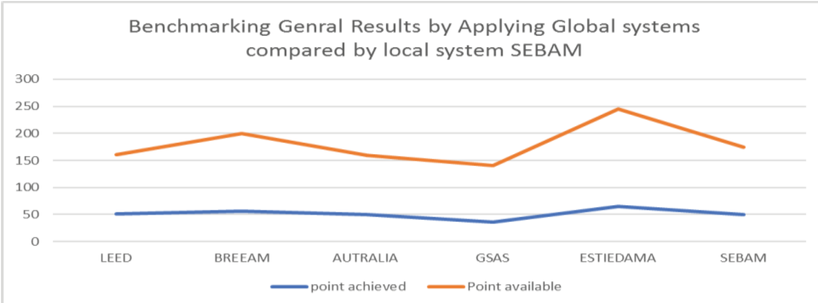



**Fig. 4.11: Benchmarking case study general results by applying global systems compared by local system SEBAM**

Note that the results by the global systems and the local system SEBAM are nearly to each other there is some differences in details and weight. Figure 1, Table 1 showing the results of SEBAM it is 50%, while Figure 2, Table 2 showing the result of Australia GB it is 50%, in addition to that Table 3, Figure 3 showing the result of BREEAM it is 51 points, also Figure 4, Table 4 showing the results of LEED it is 51 points, Figure 5, Table 5showing the result of ESTEDAMA it is 65 points (2 pearls) finally; Table 6, Figure 6 showing the result of GSAS it is 36 (2 stars).Figure 7 and figure 8 concluded the results.

Although the results are near to each other, but there are still differences in the details and weighing according to the details because of the local environment and social and economic differences.

## 4.6. Discussion of the results

The case study was analyzed first by the research method of assessment, the applied the solutions found are the good accessibility, parking with cover shed, concrete structure, bricks, glass and aluminium. Vaults over the bedrooms, double-height with a green plant. Large garden with shrubs and trees. Solar panel. Recycled greywater. A windcatcher further accentuated this and underground brick ducts for supplying cool filtered air. Small high-level openings siphoned the hot air and enhanced convectional currents.

Although, this sample was analyzed by the five global assessment methods, which are: GBCA, BREEAM, LEED, ESTIDAMA AND GSAS, SEBAB sustainable building assessment method in chapter six to find out the global challenges in applying the sustainable assessment methods in Greater Khartoum.

*1. The site and management*

The applied solutions such as GBCA: building information committed to performance, metering and monitoring, construction environmental management, BREEAM: Site selection, the ecological value, in addition, LEED added building exterior and hard cape management plan, erosion control, alternative transportation, heat island effect and lighting control. In addition, ESTIDAMA added improved outdoor thermal comfort, private outdoor space, public transportation, parking space, lighting control, in addition to that, GSAS added transportation load, proximity to the existing district, solid waste management. In spite of the fact that the not applied solutions such as AGBC: green star certified professional, commissioning and tuning, adaptation and resilience, but BREEAM is not Appling minimizing the impact on existing site ecology, enhancing site ecology, and long term has an impact on biodiversity. However, LEED is not Appling to LEED - certified design, management plan, site development, stormwater control despite, ESTIDAMA is not Appling urban system assessment outdoor thermal strategy, rated communities, accessible community facilities, active urban environment, bicycle facilities and travel plan. GSAS: None.

*2. Water Facilities*

The applied solutions such as GBCA: Portable water and BREEAM added water consumption, water monitoring, and water-efficient equipment, also LEED applied plumbing factor, water-efficient, landscape, also, ESTIDAMA added water use reduction, and GSAS applied water consumption. However, The not applied solutions such as GBCA: partial, but BREEAM not applied water leak detection, however, LEED not applied indoor plumping efficiency, water performance measurement and cooling tower, on the other hand, ESTIDAMA is not applied interior water use reduction, exterior water monitoring, improve interior water reduction, exterior water use reduction, and water monitoring and stormwater. GSAS: partial

*3. Energy*

The applied solutions such as GBCA: Greenhouse Gas Emissions, peak electricity reduction, and BREEAM: reduction of energy use, energy monitoring, external lighting, low carbon design, energy-efficient transportation system, also LEED: energy efficiency, energy metering in addition to that, ESTEDAMA: renewable energy, and GSAS: energy delivery performance. In spite of the fact that the

not Applied Solutions such as GBCA: all solution, but BREEAM: energy efficient cold storage, energy- efficient transportation system , however, LEED: energy efficient best practice, energy performance, fundamental refrigerant, exiting building commissioning, building automation system emission reduction reporting although.

ESTIDAMA: minimum energy performance, energy monitoring, and ozone impact improve energy performance, cool building strategies, vertical transportation, peak load reduction but, GSAS: fossil fuel conservation, CO2 emissions, NOx, Sox matter.

*4. Material*

The applied Solutions such as GBCA applied responsible building materials, construction and demolition waste and, BREEAM applied responsible sourcing of materials, insulation, design for durability, material efficiency, hard landscaping and boundary protection in addition, LEED added sustainable purchasing, sustainable furniture, sustainable food. In addition, ESTIDAMA added non-polluting material, design for flexibility, modular flooring system, design for durability, recycling materials, waste management, and GSAS added regional material, responsible sourcing materials, recycled materials. However, The not applied solution such as GBCA: life cycle impact, sustainable products, but BREAM not added Life cycle impact on the other hand LEED not added sustainable policy, solid waste policy, reduction mercury lamps, ESTIDAMA not added design material reduction, design for disassembly, building reuse, material reuse, regional material, rapidly renewable material, reused certified timber, and improve operation waste management, organic waste management. GSAS not applied material reuse and LCA.

*5. Indoor environment*

The applied solutions such as GBCA applied indoor air quality, acoustic comfort, lighting comfort, visual comfort, indoor pollutants, and thermal comfort. BREEAM applied None, LEED: Best management practice, control lighting, daylight and view, sustainable cleaning equipment, chemical control in addition to that, ESTIDAMA applied ventilation quality, materials emissions, indoor air quality, thermal zone, views, daylight, noise control, secure environment. GSAS: has no indoor environment category.

Not applied solutions such as GBCA: None

BREEAM: applied all, LEED did not apply environmental tobacco control, green cleaning, occupant comfort, ESTIDAMA not applied thermal comfort control, thermal comfort modelling and, GSAS: applied all.

Addition of New categories such as GBCA: emissions, innovations, but BREEAM added health wellbeing, transportation, waste, pollution, innovation , on the other hand, LEED added innovation, regional priority, but ESTIDAMA added integrated design process, natural system, innovation. On the other hand, GSAS added urban connectivity, culture value, management and operation.

There are fixed 5 main categories between these global assessment methods which are: sustainable site, indoor environment quality, building material, water efficiency, energy efficiency, on the other hand, each system added additional categories like GBCA added management and ecological category and emission. ESTIDAMA added integrated development process, livable community and innovation. LEED added innovation and regional priority. BREEAM added health wellbeing, transport, waste, pollution and innovation. GSAS added urban connectivity, culture value and management. Because of these additional categories and different sub-issues, the result was varying from system to another: The conclusion from the analysis of "one case study" by the global systems are different variation in the result: GBCA (63, five STAR), BREEAM (68, very good), LEED (60, gold). GSAS (5 stars), ESTIDAMA (3 pearls). For all not applied solutions, the reasons are educational and economic reasons. Solutions need to be educated like green star certified professional, LEED-certified design, by having workshops or continuous educations courses in specific assessment methods. Solutions not applied for its highly expensive solutions like energy-efficient transportation system. It is very important to study their local environmental, special, technological conditions in the local environment in Greater Khartoum and apply economical solutions suitable to local environmental, social and economic value. The research method of assessment studied the conditions of Greater Khartoum in chapter three and added three categories suitable to local environmental social and economic conditions, detailed by the passive solutions can be applied in our houses, which are, building form, outdoor environment and sustainable design process to add educational value.

## 4.7. Conclusions

The conclusion from the analysis of "one case study" by the global systems are different variation in the result: The proposed research method of assessment SEBAM (50 points), GBCA (63, 5 stars), BREEAM (66, very good), LEED (58, silver). GSAS (2 stars), ESTIDAMA (2 pearls) because of the difference in the main categories and sub- issues to achieve their local goals in the environment, culture, social and economic value. On the followings, the researcher discusses the result to find out the applicable solutions to Greater Khartoum and not applicable solutions to highlight them as global challenges.

*1. Site and management*

The research come-out of the need to apply solutions such as GBCA: building information, commitment to performance, metering and monitoring, construction environmental management.

BREEAM: site selection, ecological value. LEED: building exterior and hard cape management plan, erosion control, alternative transportation, heat island effect and lighting control. ESTIDAMA: improved outdoor thermal comfort, private outdoor space, public transportation, parking space, lighting control. GSAS: transportation load, proximity to the existing district, solid waste management.

*2. Water facilities*

The research Applied solutions in water facilities such as GBCA: Portable water. BREEAM: water consumption, monitoring and efficient equipment. LEED: Plumbing factor, water-efficient landscape. ESTIDAMA: water use reduction. GSAS: water consumption.

*3. Energy*

The research applied solutions in energy efficiency such as GBCA: Greenhouse gas emissions, peak electricity reduction. BREEAM: Reduction of energy use, energy monitoring, external lighting, low carbon design, energy efficient transportation system. LEED: energy-efficiency, energy metering. ESTEDAMA: renewable energy. GSAS: energy delivery performance.

*4. Material*

The research applied solutions in the material such as GBCA: Responsible building materials, construction and demolition waste. BREEAM: Responsible sourcing of materials, insulation, design for durability, material efficiency, hard landscaping and boundary protection. LEED: sustainable purchasing, sustainable furniture, sustainable food. ESTIDAMA: Non-polluting material, design for flexibility, modular flooring system, design for durability, recycling materials, waste management. GSAS: regional material, responsible sourcing materials, recycled materials.

*5. Indoor environment*

The research Applied solutions an indoor environment such as GBCA: indoor air quality, acoustic comfort, lighting comfort, visual comfort, indoor pollutants, thermal comfort. BREEAM: None. LEED: Best management practice, control lighting, daylight and view, sustainable cleaning equipment, chemical control. ESTIDAMA: ventilation quality, materials emissions, indoor air quality, thermal zone, views, daylight, noise control, secure environment. GSAS: None

*New categories added by the global systems.*

GBCA: emissions, innovations. BREEAM: health wellbeing, transportation, waste, pollution, innovation. LEED: Innovation, the regional priority. ESTIDAMA: integrated design process, natural system, innovation. GSAS: urban connectivity, culture value, management and operation.

There are fixed 5 main categories between these global assessment methods which are: sustainable site, indoor environment quality, building material, water efficiency, energy efficiency, on the other hand, each system added additional categories like GBCA added management and ecological category and emission. ESTIDAMA added integrated development process, livable community and innovation. LEED added innovation and regional priority. BREEAM added health wellbeing, transport, waste, pollution and innovation. GSAS added urban connectivity, culture value and management because of these additional categories and different sub-issues. The result was varying from system to another: The conclusion from the analysis of "one the case study" by the global systems are different variation in the result: GBCA (63, five STAR), BREEAM (68, very good), LEED (60, gold). GSAS (5 stars), ESTIDAMA (3 pearls).

For all not applied solutions, the reasons are educational and economic. Solutions need to be carefully selected; like green star certified professional, LEED-certified design, by having workshops or continuous educational courses in specific assessment methods. Solutions are not applied for its highly expensive solutions; like energy-efficient transportation system. It is very important to study our local environmental, special, technological conditions in the local environment in Greater Khartoum and apply economical solutions that are suitable to the local environmental, social and economic value. The research method of assessment studied the conditions of Greater Khartoum in chapter three and added three categories suitable to local environmental social and economic conditions, detailed by the passive solutions can be applied in their houses, which are, building forms, outdoor environment and sustainable design process to add educational value.

## 4.8. Recommendations

The case study was analyzed by the proposed research method of assessment (SEBAM) and by the five global assessment methods, which are GBCA, BREEAM, LEED, ESTIDAMA, GSAS to find out the global challenges in applying the sustainable assessment methods in Greater Khartoum.

*1. Site and management*

The research recommends keeping and increasing their applied solutions in the sustainable site like:

Building information, committed performance, metering and monitoring, construction environmental management, site selection, ecological value, building exterior and hard cape management plan, erosion control, alternative transportation, heat island effect and lighting control., improved outdoor thermal comfort, private outdoor space, public transportation, parking space, lighting control, transportation load, proximity to existing district, solid waste management.

The research recommends adopting such solutions as:

green star certified professional, commissioning and tuning, adaptation and resilience, minimizing impact on existing site ecology, enhancing site ecology, long term impact on biodiversity, LEED-certified design, management plan, site development, stormwater control, urban system assessment outdoor thermal strategy, rated communities, accessible community facilities, active urban environment, bicycle facilities and travel plan.

*2. Water Facilities*

The research recommends keeping and increasing our applied solutions in water efficiency like:

Portable water, water consumption, water monitoring, water-efficient equipment, plumbing factor, water efficient landscape, water use reduction and water consumption.

The research recommends adopting such solutions as:

Water leaking detection, indoor plumping efficiency, water performance measurement and cooling tower, Minimum interior water use reduction, exterior water monitoring, improve interior water reduction, exterior water use reduction, and water monitoring and stormwater.

*3. Energy*

The research recommends keeping and increasing the applied solutions in energy such as Greenhouse Gas Emissions, peak electricity reduction, reduction of energy use, energy monitoring, external lighting, low carbon design, energy efficient transportation system, energy-efficiency, energy metering, renewable energy and energy delivery performance.

The research recommends adopting solutions such as:

Energy-efficient cold storage, energy efficient transportation system, Energy-efficient best practice, energy performance, fundamental refrigerant, exiting building commissioning, building automation system emission reduction reporting, minimum energy performance, energy monitoring, ozone impact, improve energy performance, cool building strategies, vertical transportation, peak load reduction., fossil fuel conservation, CO2 emissions, NOx, Sox matter.

*4. Material*

The research recommends keeping and increasing their applied solutions in material such as Responsible building materials, construction, demolition of waste, responsible sourcing of materials, insulation, design for durability, material efficiency, hard landscaping and boundary protection. sustainable purchasing, sustainable furniture, sustainable food, non-polluting material, design for flexibility, modular flooring system, design for durability, recycling materials, waste management, regional material, responsible sourcing materials, recycled materials.

The research recommends adopting such solutions as:

Life cycle impact, sustainable products, Life cycle impact, sustainable policy, solid waste policy, reduction mercury lamps, design material reduction, design for disassembly, building reuse, material reuse, regional material, rapidly renewable material, reused certified timber, and improve operation waste management, organic waste management, material reuse, LCA.

*5. Indoor environment*

The research recommends keeping and increasing their applied solutions in material: Indoor air quality, acoustic comfort, lighting comfort, visual comfort, indoor pollutants, and thermal comfort, best management practice, control lighting, daylight view, sustainable cleaning equipment, chemical control, ventilation quality, materials emissions, indoor air quality, thermal zone, views, daylight, noise control, and secure environment.

The research recommends adopting solutions such as:

Environmental tobacco control, green cleaning, occupant comfort, thermal comfort control, and thermal comfort modelling.

The research strongly recommends applying the common categories shared by the five global systems in the research method of assessment, which, are sustainable site, indoor environment quality, energy efficiency, water efficiency and building material.

The research recommends adding additional categories like the educational value in learning green star certified professional, LEED certified design, by having workshops or continuous educational courses in specific assessment methods.

The research recommends adding suitable categories to their local environment. Solutions are not applied for its high expensive solutions like energy-efficient transportation system. It is very important to study their local environmental, special, technological conditions in the local environment in Greater Khartoum and apply economical solutions suitable to local environmental, social and economic value.

The case studied added three categories suitable to local environmental, social and economic conditions, detailed by the passive solutions can be applied in their houses, which are; building form, outdoor environment and sustainable design process to add educational value.

## 4.9. Acknowledgement

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# CHAPTER FIVE

# IMPACT OF KHARTOUM REFINERY GASEOUS BY-PRODUCTS ON THE ENVIRONMENT

# Impact of Khartoum Refinery Gaseous By-Products On The Environment

## 5.1. Abstract

Sudan has become one of the oil producing countries since 2000. Petroleum as an energy source represents 16 % of the energy balance of the country. The processes of prospecting, transportation, refining and utilization of petroleum may have serious negative impacts on the environment. This study focuses on the determination of the nature and concentration of the main gases ensuing during the process of oil refining, at Khartoum Refinery. Also, investigation into means and ways adopted by the Refinery to reduce the negative impact of gaseous by-products on the environment are reviewed. The gaseous by- products analyzed include SO2, NOX and CO. It is found that the analytical results of the gaseous by –products are compatible with the Chinese, Global Bank Guide and The Sudanese Standards.. However, the methods adopted in controlling the pH and the chemical oxygen demand needs revising. Some recommendations are proposed in order to curb the impact of this industry on the environment.

*Keywords*: Khartoum Refinery, Refinery gaseous by products, Refinery geaseous management , Refinery gaseous Environmental Impact.

## 5.2. Introduction

There is increasing concern among scientists and decision-makers about the negative impact created by the use of various types of energy on the environment. Problems of desertification, global heating, climatic changes and drought surmount the deleterious impacts of these activities. Since energy is inevitable in everyday life and in agricultural and industrial activities; and that the need for it is continual, great attention is nowadays being directed towards research into the deleterious impacts of energy use on the environment. The seeking of ways and means for reducing such impacts is becoming of paramount importance. Sudan has become one of the oil producing countries since 2000. Petroleum as an energy source represents 16 % of the energy balance of the country. Taking into account the petroleum industry benefits to the economy of Sudan and the expected amelioration of life standards of its people, the processes of prospecting, exploration, transportation, refining and utilization of petroleum may have serious negative impact on the environment. This study concentrated on determining gaseous by- products at Khartoum Refinery and its impact to the surrounding environment. Samples were tested at the Khartoum Refinery lab equipment official laboratory, permission was given because there was none specialization laboratory in gas monitoring in Khartoum except the refinery labs. Obtained results were compared with Chinese and Sudanese Standards set up for the Refinery by products.

## 5.3. The Literature Review

Hassan, 1981 Wrote an M.Sc. thesis on the traffic and noise pollution in central Khartoum city area .The thesis focused on air pollutants such as carbon monoxide and sulphur dioxide and their effects on human beings. (Van, 1982) investigated the air pollution control methods and equipment in the oil refining industry. (Bakhiet, 1999) studied the effects of the liquid petroleum gas as an engine fuel in Khartoum State. (Mining, 2014) The Ministry of Energy and Mining wrote a general report on the impact of petroleum industry on the environment .The report surveyed the general aspects of the impact without details or emphasis on the gaseous products of the refining process. The Institute of Environmental Studies (Studies, 2014) published the proceedings of the seminar on "Health Education". The seminar dealt with acid rain, greenhouse effect and the gaseous pollutants like NOX, SO2 and CO.

***Khartoum Refinery Company (KRC)***

Khartoum Refinery Company limited (KRC) is a joint venture between the Chinese National Petroleum Corporation (CNPC) and the Ministry of Energy and Mining (MEM) of Sudan, each holding fifty percent of the shares. The joint venture agreement of the Refinery was signed in March, 1997 and the construction was officially started in May 1998. The plant was formally put into production in 2000, with annual output of 2.2587 metric tons /year. This study focuses on the gaseous pollutants emanating from the Khartoum Refinery situated at Al Gaili town, about 4 Km from Khartoum the Capital of

Sudan and flowing directing to the river during the processes of oil refining. (Abdelmoneim, 2015)

### 5.3.1. Refinery main production

The annual output is 2.2587 million tons (mt ) of oil products such as gasoline, jet fuel, diesel (naphtha), fuel oil, liquefied gas (LPG), kerosene and benzene (mogas). Among them the gasoline is unleaded; the diesel is of high quality with low sulphur, low aromatics and light colour. Due to its low Sulphur content, Liquid Petroleum Gas (LPG) is a clean fuel satisfying the environment protection requirements.

### 5.3.2. The Environmental Impact of gaseous by products

This work focuses on the gaseous pollutants, namely nitrogen oxides, sulphur dioxide, sulphur trioxide and carbon monoxide produced during oil refining at the Refinery. All the above, so called, green house gases pollute the atmosphere during combustion of petroleum products, whether during transportation, electricity generation or during crude oil refining. The main stream view among the scientific community is that increase in the emission of green house gases will lead to rise in global temperature beyond normal levels. Over 50% of these gases are produced from the combustion of fossil fuels .The consequences of higher temperatures will lead to gradual rise in sea level as well as in changes in global climate, which could result in the flooding of many coastal areas and disruption of various agricultural schemes (e.g. Institute of Environmental Studies, 2002). In the following account the negative impact of these gases will be reviewed.

### 5.3.3. Carbon monoxide

It is a colorless, odourless gas of molecular weight 28 and specific gravity the same as that of air. Carbon monoxide affects human and animal health by combining more readily than oxygen with the haemoglobin in the red blood cells. This reduces the normal supply of oxygen to the body tissues. However, the resultant oxygen deficiency is reversible, but sometimes-severe exposures may not be reversible.

The effect of carbon monoxide on humans is categorized as acute or chronic. Acute effects depend on the concentration of carbon monoxide, length of time of exposure, the degree of exertion and personal susceptibility.

Exposure to carbon monoxide for 10-45 minutes in a concentration of 10,000 ppm leads to unconsciousness and death. Levels of carbon monoxide concentration between 100 and

10,000 ppm for 3-15 minutes can cause headache, dizziness and nausea. At lower levels, although no obvious symptoms occur, possible effects on the central nervous system may in some cases lead to impaired vigilance or delayed reaction time (Hassan, 1981).

### 5.3.4. Sulphur dioxide

It is a colorless, irritant gas having a characteristic odour and taste and a molecular weight of 64.07. An average individual can detect Sulphur dioxide concentrations of 0.3 to 1ppm by taste rather than smell. A concentration of 3 ppm has an easily detectable odour. Concentrations of 6-12 ppm in the atmosphere cause immediate irritation to the nose and throat. Irritation of the eyes occurs at a concentration of about 20 ppm. If inhaled, the gas dissolves readily and affects the upper respiratory tract .In acute cases it may cause odema of the lungs and respiratory paralysis. Chronic effects on the senses of smell and taste are likely to occur on exposure for a period of over a year to variable concentrations from 30 ppm with occasional peaks of 100 ppm. The maximum permissible average concentration for ambient air three hours is 0.5 ppm, while the maximum permissible for 24 hours is 0.14 ppm; and the permissible annual arithmetic mean is 0.03 ppm (Hassan, 1981)

### 5.3.5. Nitrogen oxides

Nitrogen combines with oxygen to form the most common of the conventional pollutants - oxides of nitrogen (NOX) indoors exposures occur because NOX is producing in unventilated rooms where gas-fires, stoves, as well as kerosene heaters are used.

In fact NOX is a threat to human and animal health as follows:

- Exposure to high levels of NOX commonly impairs lung defenses to common infections.
- Long -term studies indicated that exposures to high levels of NO2 can lead to chronic respiratory bronchiolitis by impairing the expiratory flow rate. This effect is reversible if the level of NO2 exposure is reduced.
- Acute exposures to high levels of NO2 may cause changes within the lung that, in turn, could increase bronchial responsiveness, particularly in asthmatics.
- Any inhaled substance (including NO2) that can cause an inflammatory response, will enhance the susceptibility to allergens.
- Animals exposed to NOX are less able to ward off bacterial infections.

- NOX affects ozone layer. Fine particles and acids require strict controls to minimize death and serious illness.

### 5.3.6. Objectives/Purpose of the study

To study, the nature and concentration of the various gases ensuing during the processes of refining at Khartoum Refinery.

To review methods of treatment and management procedure followed by Khartoum Refinery in decreasing pollutants to the minimum possible level.

To propose recommendations to curb any possible environmental hazards.

## 5.4. Methodology

**Khartoum Refinery Gaseous By Products.**

### 5.4.1. Location and accessibility of the study area

The Khartoum Refinery is located on a semi rocky-desert land 15 km Northeast of Al- Gaili village, and about 12 km. East of the River Nile (Fig.1). Small villages are scattered around the Refinery area whose inhabitants are mainly farmers and sheepherders, either illiterate or having incomplete primary education. However, some young men work as casual labourers in the Refinery (Mining, 2014)

### 5.4.2. The Refinery Units

The Refinery consists of the following production units (Mining, 2014):

- Crude Distillation Unit (CDU), capacity: 2.5 mt/y, consisting of an electric desalter and crude distillation products refining.
- Residual Fuel Oil Catalytic Cracking Unit (RFCC), capacity: 1.8 m t/y, consisting of reaction and regeneration ,distillation, absorption and stabilization, energy recovery , Sulphur and mercaptan removal sections.
- Reforming Unit, capacity: 150000 t/y and consisting of pre-treatment and reforming sections.
- Diesel Hydro Treating Unit (DHT), capacity: 500000 t/y, consisting of hydrogen recovery and diesel hydrogenation sections.
- Sour Water Stripping Unit, capacity :400000 t/y.

- Utilities include: a power plant, a waste water plant, an air separation and compression unit and a river water purification plant (1500 $m^3$/h). (Abdelmoneim, 2005, 2015), (Abdelmoneim, 2015)

### 5.4.3. Process Description

*The Refinery Gaseous by products:*

It is expected that the Refinery can cause gaseous and liquid pollution, bad smells and noise. The major gas pollutants include hydrocarbon vapours, nitrogen oxides, Sulphur dioxide, Sulphur trioxide, hydrogen sulphide and carbon monoxide (Mining, 2014). The major potential sources of some gaseous effluents from the Refinery are shown in Table (1).

- This study monitored nitrogen oxides, Sulphur dioxide and carbon monoxide.
- The measured was taken during the period 2/Agues/2014 to 24/Agues./2014
- Using the records adopted by Khartoum Refinery Company in the Gaseous laboratory.
- The researcher asked for permission to record the analysis by (KRC) because there are no gases laboratory specialist in Refinery by product at Khartoum.
- Daily records was obtained at 12.00 pm mid-day directly from the screen device. The methodology revised the method applied by Khartoum Refinery Company, The Nile Blende Crude Oil contains about 0.04-0.06 wt % sulphur, ending up in the sour water coming from the Crude Distillation Unit overheads (CDU), Residual Fuel- oil Catalytic cracking unit Condensates (RFCC) and The Diesel Hydro Treating Unit (DHT) . It is degassed as $H_2S$ at the Sour Water Stripping Unit which has a capacity of 0.4 mt/y . The $H_2S$ obtained is then sent straight to the flare. In addition, On Addison to that, the Nile Blende Crude Oil contains only traces of nitrogen. The gas is stripped from the collected waste sour water at the Waste Water Stripping Unit where it is transformed into $NH_3$ gas and later mixed with water to form ammonia liquid and the CO gas coming from the combustion of crude oil in CDU and RFCC is burnt in the flare.
- The results were presented in tables and figures.
- The results were compared and discussed in accordance to Sudanese, Global Bank and Chinese Standards for Refinery Gas Monitoring.
- A set of conclusion was written.


Refinery at sunset


Crude distillation Unit (CDU)

Residual oil catalytic cracking Unit (RFCC) .
and Reforming Unit(REF)



Distillation Columns Building (DCS)
(Fractionator)

Tanks of Liquid petroleum gaz.
(Spherical tanks)

**Figure 5.1. Showing the Refinery and its main units**

| Effluents | Potential sources |
|---|---|
| $SO_2$,$SO_3$,$H_2SO_4$ | Combustion furnaces and boilers, |
| | $H_2S$ flares ,catalyst regenerators heating System . |
| Hydrogen sulphide | Vent from CDU ,deSulphurizer plant, waste water |
| Hydrocarbons | Flares, storage tanks, sampling operations, |
| | open effluent water separators ,catalyst regenerators. |
| Carbon monoxide | Catalyst regenerators, decocking operation, motor- |
| | driven compressors. |
| Dusty materials | Catalyst regenerators, combustion in boilers and |
| | furnaces, decocking. |
| Nitrogen oxide | Combustion processes, flares, catalyst regeneration |
| Bad smelling gas | Storage tanks, open wastewater separators, |
| | plant sections. |

**Table 5.1: Main gaseous effluents from the Refinery.** Source: (Mining, 2014)

### 5.4.3. Analytical equipment

*See appendix-1 for the equipment*

This work is concerned with the analysis of the gaseous by-products, resulting from crude oil refining at Khartoum Refinery. The gaseous by- products analyzed include $SO_2$, $NO_X$ and CO. These were analyzed at the Refinery laboratories using $SO_2$ analyzer (for $SO_2$ determination), $NO_X$ analyzer (for $NO_X$ determination) and CO analyzer (for CO determination).

The measurements were taken during the period 02/August/2014 to 24/August /2014 when $NO_X$, $SO_2$ and CO were recorded at midday as average readings. During the field visits, the results of the analysis are read off directly from the smart screen attached to each device. $SO_2$, $NO_X$ and CO were analyzed using the following monitor lab analyzers at Khartoum Refinery Company ( KRC):

- ML 9850-sulphur dioxide analyzer.
- Carbon Monoxide analyzer.
- Nitrogen oxides analyzer, (See Apendix-1).

The measurements were taken during the period 2/August/2014 to 24/August/2014 when $SO_2$, $NO_x$ and CO were recorded midday as average readings.

## 5.5. Result/Findings

1. Table (2) shows the results of analyses of the gases $SO_2$, NOX and CO. The records were done during the period 2/08/2014 to 24/08/2014. Using the equipment available on Khartoum Refinery Company, which had screen. The records were taken at 12.00 pm at mid-day.
2. The $SO_2$ values range between 0.004 mg/m³ and 0.14 mg/m³, with the majority of readings falling between 0.11 and 0.18 mg/m³. Comparing the result by Chinese, Sudanese and the Glogal Bank standards for gaseous by-products the result was compatible to the maximum level of the standards which are: 0.25 mg/m3, 0.35 mg/m3 and < 0.04 ppm respectively.
3. The $NO_x$ values range between 0.001mg/m³ and 0.009mg/m³, with about 70% of the analyses ranging between 0.003-0.007 mg/m³. Comparing the result by Chinese, Sudanese and Glogal Bank standards for gaseous by-products the result was compatible to the maximum level of the standards which are: 0.15 mg/m3, 0.40 mg/m3 <0.40 respectively.
4. On the other hand, the CO values range between 0.15 mg/m³ and 0.49 mg/m³, with about 60% of the readings falling between 0.21-0.34 mg/m³. Comparing the result by Chinese, Sudanese and Global Bank standards for gaseous by-products, the result was compatible to the maximum level of the standards, which are 6.00 mg/m3, 10.00 mg/m3 and 10.00 mg/m3.respectively.
5. On the other hand, it was founds that the instruments need maintaining and upgrading to the most efficient equipment's (see appendix-1).
6. On addition to that, the instrument (data sheet) should be available on the gaseous laboratory.
7. The study recommended increasing the plantation around and inside the refinery and make a green buffer zone between the employee housing compound and the refinery process and working areas.

Table (2) on the appendix: Results of gaseous analysis using Monitor Lab Analysers. The temporal variations in the SO2, NOX and CO contents graphically represented in Figs. 1, 2 and 3, respectively.

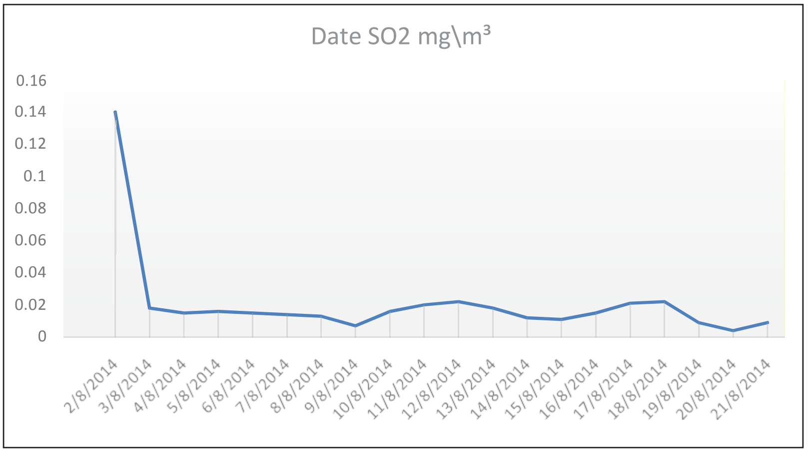


**Fig. 5.2. Plot showing the variation of SO2 with Time**

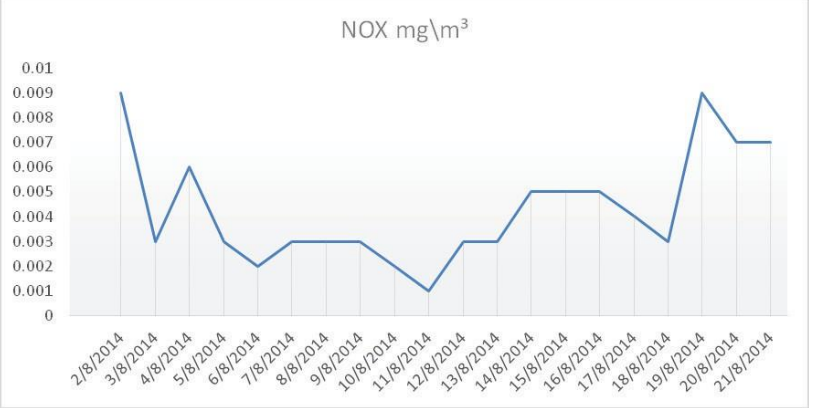


**Fig. 5.3. Plot showing the variation of NOX with Time**

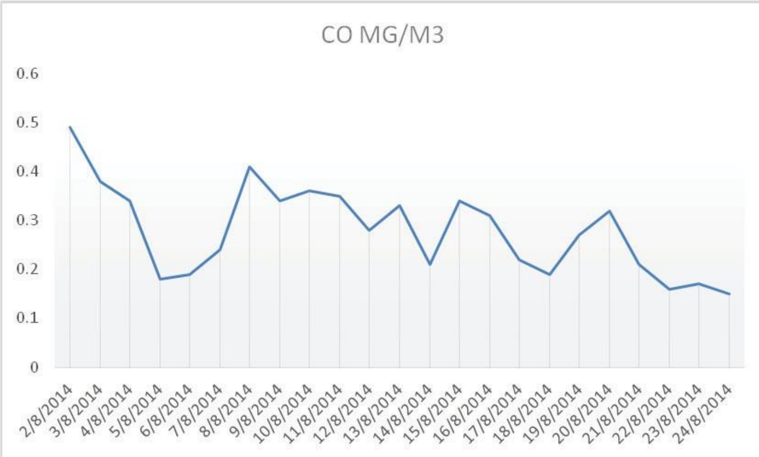


**Fig 5.4. Plot showing the variation of CO with Time**

## 5.6. Discussion

As mentioned earlier the gases SO2, NOX and CO liberated during petroleum distillation at Khartoum Refinery were analyzed in the period from 2/08/2014 to 24/08/2014. The analysis was taken directly from smart screen in the instruments inside gaseous labs during this period. The Chinese standards have been applied in the design construction and processing technology at Khartoum Refinery. However, the results of the analyses will be discussed in the light of the Chinese Standards, the Global Bank Guide for Air Quality and the Sudanese Standard Limit for Gaseous Emissions from petroleum refining.

### 5.6.1. The SO2 gas

Table (2) shows the results of analyses of the gases SO2, NOX and CO. The SO2 values range between 0.004 and 0.14 mg/m$^3$, with the majority of the readings falling between 0.11 and 0.18 mg/m$^3$.

Comparing these results with the Chinese standards shown in (Table3), the maximum permissible limit of SO2 emission is 0.25 mg/m3; while it is <0.04ppm in the Global Bank Guide (Table 4), and 0.36 mg/m3 in the Sudanese Standards (Table 5).

So the SO2 emission levels are compatible with those standards and consequently, there are no serious SO2 levels emitting from the Refinery. However, The Nile Blende Crude

Oil contains about 0.04-0.06 wt % sulphur, ending up in the sour water coming from the Crude Distillation Unit overheads (CDU), Residual Fuel- oil Catalytic cracking unit Condensates (RFCC) and The Diesel Hydro Treating Unit (DHT). It is degassed as $H_2S$ at the Sour Water Stripping Unit which has a capacity of 0.4 mt/y. The $H_2S$ obtained is then sent straight to the flare.

### 5.6.2. The NOX gases

NOX values range between 0.001 and 0.009 mg/m³, with about 70% of the results falling between 0.003 and 0.007 mg/m³. Comparing these results with the Chinese standards (Table3), the maximum permissible limit of NOX emission is 0.15 mg/m3; while it is <0.05ppm in the Global Bank Guide (Table 4) and 0.40 mg/m3 in the Sudanese Standards (Table 5).

So the NOX emission levels are compatible with those standards and consequently there are no serious levels of NOX emitting from the Refinery. In fact, the Nile Blende Crude Oil contains only traces of nitrogen. The gas is stripped from the collected waste sour water at the Wastewater Stripping Unit where it is transformed into $NH_3$ gas and later mixed with water to form ammonia liquid.

### 5.6.3. CO gas

CO values range between 0.15 and 0.49 mg/m³, with about 60% of the analyses falling between 0.21 and 0.34 mg/m³.

Comparing these results with the Chinese standards (Table 3), the maximum permissible limit of CO emission is 6.00 mg/m3; while it is 10.00 ppm in the Global Bank Guide (Table 4) and 10.00 mg/m3in the Sudanese Standards (Table 5). So the CO emission levels are compatible with those standards and consequently, there are no serious levels of CO emitting from the Refinery. In fact, the CO gas coming from the combustion of crude oil in CDU and RFCC is burnt in the flare.

Table (6) shows the maximum determined values for $SO_2$, NOX and CO gases for easy comparison with the Chinese Standards, Global Bank Guide and the Sudanese Standards.

**Table 5.2. Chinese standards used for SO2, NOX and CO gases**

| Parameter | Hazardous limit for humans |
|---|---|
| SO2 | 0.25 mg/m³ |
| NOX | 0.15 mg/m³ |
| CO | 6.00 mg/m³ |

**Table 5.3. Global Bank Guide for Air Quality. (Mining, 2005)**

| Parameter | Hazardous limit for humans |
|---|---|
| SOx | <0.04 ppm |
| NOX | 00.05 ppm (24 hrs.) |
| CO | 10.00 ppm (8 hrs.) |

**Table 5.4. Sudanese Standards Limits of Gaseous Emissions Resulting From Petroleum Refining (Mining, 2005)**

| Parameter | Hazardous limit for humans |
|---|---|
| SO2 | 00.36 mg/m3 |
| NOX | 00.40 mg/m3 |
| CO | 10.00 mg/m3 |

**Table 5.5. Comparison of the Maximum values determined for SO2, NOX and CO gases with the Chinese, the Global Bank Guide and the Sudanese Standards. (Mining, 2005)**

| Parameter | Maximum Value mg/m3 | Chinese Standards mg/m3 | Sudanese Standard mg/m3 | Global bank guide ppm |
|---|---|---|---|---|
| SO2 | 0.14 | 0.25 | 00.36 | < 0.04 |
| NOX | 0.009 | 0.15 | 00.40 | <0.05 |
| CO | 0.49 | 6.00 | 10.00 | 10.00 |

## 5.7. Acknowledgement

This humble effort would not have been possible without the help of others. I would like to thank my supervisor Dr. Abdel-Halim Hassan El-Nadi for his continues and exceptional help and guidance. I would also like to extend my thanks to the KRC engineers for acquainting me with the different activities in the various Units of the KRS and helping me with the analysis of SO2, NOX and CO. I should also thank the staff of the Ministry of Energy and Mining and the Sudan Petroleum corporation for access to their reports. My thanks should be extended to the Central Petroleum Laboratories (CPL). My Thanks should be extending to Dar Al Uloom University staff.

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# Appendix

APENDIX-1. SUGGESTED EQUIPMENT FOR UPDATING AND THEIR DATA SHEET

**Fig. 5.5: Refinery and other petroleum gases containing H2, O2, N2, CO, H2S, CO2 measurements**

Refinery gases arise from refining operations on liquid hydrocarbon feed stocks. Composition of these gases varies widely depending on what process generates them. Typically refinery gases consisting of hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, and C1-C5 saturated and unsaturated hydrocarbons. Some C6's and H2S may also be present. Refinery gas analyzers are an integral part of any refinery lab and provide valuable information that allow refiners to monitor and optimize catalytic and other processes, establish market value of a gas when sold to the chemical industry and enable the study of gaseous products from the process under study or development.

Agilent provides a family of factory tested - ready to use GC analyzers for refinery gases that provide the accurate and reliable results required.

- range of analyzers for refinery and other petroleum gases containing $H_2$, $O_2$, $N_2$, CO, $H_2S$, $CO_2$ and C1-C5 plus higher chain length hydrocarbons
- Easy “out-of-the-box” operation including pre-set method parameters, data files, and checkout samples for performance verification
- Time-saving, customized reports including calculations for mole %, weight %, or volume %, and calorific value
- Laboratory applications based on Agilent's 7890 GC, the market leading gas chromatograph, and out of laboratory applications build around Agilent's 490 MicroGC system
- An optional micro-gasifier expands the analytical capabilities to liquefied gases
- A factory certified technician will perform installation and familiarization confirming that your analyzer meets Agilent’s analytical performance criteria and “ready to go” for calibration and validation by your team
- The highly efficient and rigorous packing technology used in Agilent J&W packed GC columns assures column-to-column reproducibility and ultimate efficiency.

**System GC Solution for Refinery Gas Analysis**

**Fig.5.6: GC Solution for Refinery Gas Analysis**

Gas compositions produced in refinery plants consist of hydrocarbons, permanent gases, $H_2S$, etc. Analyzing these gases is essential to control the quality of chemical products and plant operation. Shimadzu's RGA systems, available in numerous configurations, are designed to analyze various compositions in a variety of processes. In research and development for petrochemical and its catalysis field, target compounds often contain high-boiling point compounds and isomers. The Shimadzu CERGA makes it possible to precisely analyze those samples. In addition, calorific value calculation software is compliant with various calculation methods such as BTU and ISO-6976. (Shimadzu, 2015)

**Trace CO and CO2 Analysis System GC-2014TCC**

This system is designed to measure trace amount of carbon monoxide (CO), methane (CH4) and carbon dioxide (CO2) in a gas sample. The sample is loaded into a loop and injected through a 10-port valve automatically. CO and CO2 are reduced to CH4 by means of nickel catalyst and detected by flame ionization detector (FID).

Content Type: Application

Document Number: SGC-ADS-0065

Product Type: System GC, Gas Chromatography

keywords: CO, CO2, CH4, Petrochemical, Chemical, Petroleum refinery, GC-2014

Language: English

File Name: hkc114065.pdf

File Size: 149kb

(Shimadzu, 2015)

**H2S and SO2 in C2, C3, and C4 Analysis System GC-2014SUL2**

This instrument is designed to analyze for H2S and SO2 in C2, C3, and C4 hydrocarbon streams. A Sunpak-S and silicagel packed column are used to separate the sulfur components from the hydrocarbons, avoiding the quenching phenomenon which can result in the loss of detector signal thus poor sensitivity. The method can analyze both inorganic and organic sulfur compounds, providing an ideal solution that can be applied to the analysis of both natural gas and refinery gas as well as liquid samples such as organic solvents. This system may not be suitable for gasoline analysis.

Content Type: Application

Document Number: SGC-ADS-0073

Product Type: System GC, Gas Chromatography

keywords: H2S, Petrochemical, Chemical, Petroleum refinery, Photochemical, Polymer, GC-2014

Language: English

File Name: hkc114073.pdf

File Size: 130kb

(Shimadzu, 2015)

NOx and Oxygen Analyzer for Flue Gas NOA-3030

**Fig.5.7: NOx and Oxygen Analyzer for Flue Gas NOA**

NOx contained in flue gas is a cause of air pollution and is measured according to the air pollution control act. Shimadzu applied its extensive experience with chemiluminescence NOx measurements to develop the NOA-3030 NOx and Oxygen Analyzer for Flue Gas. A high-performance CPU offers self-calibration, self-diagnosis, and alarm functions. This NOx-O2 analyzer combines a simple configuration with high performance and good functionality and represents a large step forward in automatic measurement functions. (Shimadzu, 2015)

**Table 5.6: Showing the date analyzed of gases (SO2, NOX and CO) mg/m3**

| Date | SO2 mg\m³ | NOX mq\m³ | CO mg\m³ |
| --- | --- | --- | --- |
| 2/8/2014 | 0.14 | 0.009 | 0.49 |
| 3/8/2014 | 0.018 | 0.003 | 0.38 |

| | | | |
|---|---|---|---|
| 4/8/2014 | 0.015 | 0.006 | 0.34 |
| 5/8/2014 | 0.016 | 0.003 | 0.18 |
| 6/8/2014 | 0.015 | 0.002 | 0.19 |
| 7/8/2014 | 0.014 | 0.003 | 0.24 |
| 8/8/2014 | 0.013 | 0.003 | 0.41 |
| 9/8/2014 | 0.007 | 0.003 | 0.34 |
| 10/8/2014 | 0.016 | 0.002 | 0.36 |
| 11/8/2014 | 0.02 | 0.001 | 0.35 |
| 12/8/2014 | 0.022 | 0.003 | 0.28 |
| 13/8/2014 | 0.018 | 0.003 | 0.33 |
| 14/8/2014 | 0.012 | 0.005 | 0.21 |
| 15/8/2014 | 0.011 | 0.005 | 0.34 |
| 16/8/2014 | 0.015 | 0.005 | 0.31 |
| 17/8/2014 | 0.021 | 0.004 | 0.22 |
| 18/8/2014 | 0.022 | 0.003 | 0.19 |
| 19/8/2014 | 0.009 | 0.009 | 0.27 |
| 20/8/2014 | 0.004 | 0.007 | 0.32 |
| 21/8/2014 | 0.009 | 0.007 | 0.21 |
| 22/8/2014 | 0.007 | 0.006 | 0.16 |
| 23/8/2014 | 0.013 | 0.007 | 0.17 |
| 24/8/2014 | 0.01 | 0.006 | 0.15 |

# CHAPTER SIX

# IMPACT OF KHARTOUM REFINARY WASTEWATER POLLUTANTS ON THE ENVIRONMENT

# Impact of Khartoum Refinary wastewater pollutants on the environment

## 6.1. Abstract

Sudan has become one of the oils producing countries since 2000. Petroleum as an energy source represents 16 % of the energy balance of the country. The processes of prospecting, transportation, refining and utilization of petroleum may have serious negative impacts on the environment. This study focuses on the determination of pollutants in wastewater at Khartoum Refinery. Likewise, the study reviewed means and ways adopted by the Refinery to reduce negative impact of such pollutants on the environment. Wastewater pollutants analyzed included: pH, oil and grease, sulphides, phenols, nitrogen and ammonia, total suspended solids (TSS), biological oxygen demand (BOD), and chemical oxygen demand (COD). It is found that analytical results of pollutants at the outlet of treated effluent are compatible with Chinese and Sudanese Standards as regards oil and grease; phenols; nitrogen and ammonia; total suspended solids; biological oxygen demand and sulphides. This demonstrates the effectiveness of treatment methods adopted by the Refinery in dealing with the above–mentioned gaseous by-products and water pollutants. However, methods adopted in controlling pH and chemical oxygen demand need revising. Some recommendations are proposed in order to curb the impact of this industry on the environment.

*Keywords*: Khartoum Refinery, Refinery wastewater, Refinery wastewater management , Refinery waste water Environmental Impact.

## 6.2. Introduction

There is increasing concern among scientists and decision-makers about the negative impact created by the use of various types of energy on the environment. Problems of desertification, global heating, climatic changes and drought surmount the deleterious impacts of these activities. Since energy is inevitable in everyday life and in agricultural and industrial activities; and that the need for it is continual, great attention is nowadays being directed towards research into the deleterious impacts of energy use on the environment. The seeking of ways and means for reducing such impacts is becoming of paramount importance. This study concentrated on determining wastewater at Khartoum Refinery and its impact to the surrounding environment. Samples were tested at the Central Petroleum Equipment official laboratory. Obtained results were compared with Chinese and Sudanese Standards set up for the Refinery by products.

*Objectives/Purpose of the study*

1. To study of nature and concentration of pollutants in wastewater resulting from the petroleum refining process.
2. To review methods of treatment and management procedure followed by Khartoum Refinery in decreasing pollutants to the minimum possible level.
3. To determine pollutants in waste waters resulting from crude oil refining during refining process, using facilities available at the Central Petroleum Laboratories in Khartoum.
4. To propose recommendations to curb any possible environmental hazards.

## 6.3. Literature review. Methodology

### 6.3.1. Khartoum Refinery wastewater

Wastewater is one of the main liquid wastes produced during oil refining process at KRC. The wastewater discharge includes waters from the following sources:

a. Hydro-carbon polluted waters, i.e. processing water from oil processing units, bottom drainage from oil tanks, laboratory discharge, and discontinuous discharges of various utilities from polluted areas.
b. Domestic sanitary water which also joins the Refinery discharge as, water used in cooling or other treatment operations contains a number of organic and inorganic pollutants. Waters from the desalted and the condensed acidic water from CDU and RFCC contain sulphides, phenols, ammonia, H2S, and different amounts of oil. Other water pollutants include:-
c. Suspended and dissolved solids.

***Biodegradable materials measured by Biological oxygen demand (BOD). Organic matter that oxidizes with other chemicals measured with Chemical oxygen demand (COD).***

In this study, the reduction of these substances practiced by the Refinery operators to permissible levels by physical, chemical and biological means is tested. This is because polluted waste waters can affect ground water, the Nile waters quality or the soil. This is brought about by:-

***d. Intoxication of water by chemicals.***

Change in the taste, odor, color or increase in its turbidity or temperature which reduces the content of dissolved oxygen Possibility of break out of fires or explosions due to the presence of hydrocarbons. Chemical irritation, inflammation or chemical pneumonia. (KRC, 2002).

### 6.3.2. Wastewater treatment plant:

Wastewater treatment plant capacity=300m3/h and it consist of:

*1. Oil separator pond-1:*

It is a physical method, efficient for removing suspended hydrocarbons. The first step in the removal of hydrocarbons from water is usually by gravity separation .Through properly selected separator tanks with skimmers, most free oil and unstable oil emulsions can be separated from the water. It is the most economical way to remove large quantities of free oil from water after passing the water through large tanks to allow the phases to separate. The effectiveness of these tanks depends on droplet size and detention time within the tank .Oil separator reduces oil concentration to a value of 2 to 25 mg/L, with an average of 15 mg/L.

*2. Floatation pond-2 and 3:*

It is a mechanical and chemical method by using air stripping from compressors to evaporate organic compounds (VOC`s) and by adding chemicals (PAC) in order to remove dissolved hydrocarbons.

*3. Bio-chemical pond-4:*

Biological treatment is used to remove low levels of dissolved hydrocarbons from wastewater streams. Biological treatment consists of mixing oxygen and nutrients with water in a tank. The bacteria then degrades organic compounds as well as altering chemical form of heavy metals, sulphur, phenols, nitrogen and ammonia. This method is too slow for oil industry applications, because the high salinity of produced water inhibits biological growth, and hence biological treatment will not be effective in most cases.

*4. Filtration:*

One way to remove oil droplets from water is to pass the water through wet filters. This method is used also to remove suspended solids. Sand or gravel filters are common media used in this process. In some special cases when the pH of wastewater is too low or very high the KRC waste water treatment plant uses a system control by- pass in order to discharge the waste water to the oxidation pond without treatment (Petroleum Training Centre, 2004).

## 6.4. Analysis of effluent water:

In order to detect the type and concentration of pollutants present in the Refinery waste water, ten water samples were taken simultaneously, five from the inlet and five from the outlet of the waste water pond after treatment. The parameters analyzed include:-

- Oil and grease, Sulphides, Phenols, Nitrogen and Ammonia, Total suspended solids (TSS). Biological oxygen demand (BOD) and Chemical oxygen demand (COD).

### 6.4.1. Analytical equipment:

See appendix-1 for the equipment and appendix-3 for the method.

Following is a list of equipment used for wastewater analyses at the Central Petroleum Laboratories (see Appendix–1 for the details).

- UV Spectro photometer for the analyses of the sulphides, Nitrogen and ammonia and the phenols (Plate 1).
- TSS Water Bath for the analysis of total suspended solids (Plate 2).

- pH Meter for the determination of pH (Plate 3).
- COD Reactor measuring the chemical oxygen demand (Plate 4).
- Rota Vaporate (plate 5), Soxhlet Extraction (plate 6) and the Oven (plate 7) for the determination of oil and grease.
- BOD Incubator for aiding measurement of biological oxygen demand (Plate 8).

See plate 1 to 8.

## 6.5. Result/Findings

Tables (5) and (13) show results of analyses for pH, sulphide, nitrogen and ammonia, chemical oxygen demand ( COD), oil and grease, total suspended solids (TSS), phenols and biological oxygen demand (BOD) from the inlet and outlet wastewater, respectively. The levels of analysed parameters dropped as follows:- pH from 7.15 to 4.57; sulphide from 654.00 mg/L to 25.00 mg/L; nitrogen and ammonia from 47.6 mg/L to 9.96 mg/L; chemical oxygen demand from 450.00 mg/L to 327.00 mg/L; oil and grease from 128.40 mg/L to 10.00 mg/L; total suspended solids from 183.00 mg/L to 32.00mg/L; phenols from 0.2 mg/L to 0.03; while the biological oxygen demand from 40 mg/L to 12 mg/L .
*Table (16). The Results of parameters analyzed in wastewater from inlet and outlet treatment pond.*

1) Comparing these results with Chinese Standards (Table 11), and the Sudanese Standards limits of Liquid Wastes Resulting from Petroleum Refineries (Table 12), one finds that: 1)The pH value in the outlet wastewater indicates that the water is acidic and not suitable for drinking purposes.
2) The chemical oxygen demand (COD) value, in the outlet treated water is not compatible with those standards.
3) Oil and grease; phenols; total suspended solids (TSS); nitrogen and ammonia; sulphide and biological oxygen demand (BOD) values in the outlet treated water are compatible with both the Chinese and the Sudanese Standards for treated water quality. The outlet treated wastewater is not suitable for drinking, but it can be used in the evaporation pond for raising fish, plantations and cooling of engines.

It is clear from the analyses carried out in this study that the *methods adopted by the Refinery are ineffective in bringing the levels of the pH and the chemical oxygen demand* *to the permissible, harmless concentrations.* Likewise, it is clear that oil and grease; phenols; nitrogen and ammonia; the total suspended solids (TSS); the sulphide and the biological oxygen demand (BOD) values in the outlet treated water are all compatible with those standards. However, the analyses carried out in this study show that *the methods adopted by the Refinery are ineffective in bringing the levels of the pH and the chemical oxygen demand to the permissible, harmless concentrations.*

So it is clear that the control of these parameters is not effective and needs revising. Also, the discharge of these polluted waters on the ground depending on its rocky nature around the Refinery does not exclude the presence of fractures in these rocks that would render them permeable. Hence, the possibility of contamination of any water underground cannot be ruled out completely. Furthermore, the manner by which the chemicals used in oil refining are stored also needs revising. The package of recommendations suggested in this study is likely to alleviate most of the present deleterious environmental impact.

## 6.6. Discussion of the results of wastewater analyses

The major water pollutants tested in this research work included: oils and grease, sulphides, phenols, ammonia, total suspended solids (TSS), biological oxygen demand (BOD) and chemical oxygen demand (COD). These parameters were analyzed during a one and a half month period from 27/9/2004 to 11/10/2004 at the Central Petroleum Laboratories (CPL). (Table 5) shows the results of the analyses of the inlet wastewater and (Table 6) shows the results of the analyses of the outlet treated water. The results of the analyses will be discussed in the light of the Chinese and the Sudanese Standards limits of Liquid Wastes Resulting from Petroleum Refining.

### 6.6.1. The pH:

As mentioned, the pH values dropped from 7.15 in the inlet wastewater (Table 5) to 4.57 in the outlet wastewater (Table 6). Comparing these results with the Chinese Standards shown in (Table11) the permissible limit of pH ranges between 6-9; while it ranges between 6-9 in the Sudanese Standards (Table 12). So, the pH value in the outlet wastewater indicates that the water is acidic.

### 6.6.2. The Sulphides:

The sulphide values droppee from 654.00 μg/L in the inlet wastewater (Table 5) to 25 μg/L in the outlet wastewater (Table 6). Comparing this result with Chinese and Sudanese standards (Table 11 and 12), it is evident that the results of the sulphides are well above those standards (1.00 mg/L), since 25μg/L =0.025mg/L. So, the Sulphide value in the outlet treated water is compatible with those standards.

### 6.6.3. The Nitrogen and Ammonia:

The Nitrogen and Ammonia values dropped from 47.60 mg/L (Table 5) in the inlet waste water to 9.96 mg/L (Table 6) in the outlet waste water. Comparing this result with the Chinese Standards (Table 11), the maximum permissible limit of Nitrogen and Ammonia is 15 mg/L; while it is 10 mg/L in the Sudanese Standards (Table 12). So, the Nitrogen and Ammonia values in the outlet treated water are compatible with those standards.

### 6.6.4. The Chemical oxygen demand (COD):

The COD values dropped from 450.00mg/L (Table 5) in the inlet wastewater to 327.00 mg/L (Table 6) in the outlet wastewater. Comparing this result with the Chinese Standards (Table 11), the maximum permissible limit of COD is 100 mg/L; while it is 150 mg/L in the Sudanese Standards (Table 12). So, the COD value in the outlet treated water is not compatible with those standards.

### 6.6.5. Oil and grease:

Oil and grease values dropped from128.40 mg/L (Table 5) in the inlet waste water to 10.00 mg/L (Table 6) in the outlet waste water. Comparing this result with the Chinese and Sudanese Standards (Table 11 and 12), the maximum permissible limit of Oil and grease is 10 mg/L. So the Oil and grease value in the outlet treated water is compatible with Chinese Standards and Sudanese Standards for water quality.

### 6.6.6. The total suspended solid (TSS):

The TSS values dropped from 183.00 mg/L (Table 5) in the inlet wastewater to 32.00 mg/L (Table 6) in the outlet wastewater. Comparing this result with the Chinese Standards (Table 11), the maximum permissible limit of TSS 70.00 mg/L; and with the Sudanese Standards (Table 12), the maximum permissible limit is 30 mg/L.

It clear that the result of TSS is compatible with those standards.

**6.6.7. The Biological oxygen demand (BOD):**

The BOD values dropped from 40 mg/L (Table 5) in the inlet wastewater to 12 mg/L (Table 6) in the outlet waste water. Comparing this result with the Chinese and the Sudanese Standards in (Table 11 and 12) the maximum permissible limit of BOD is 30 mg/L. So, the BOD value in the outlet treated water is compatible with those standards.

**6.6.8. The Phenols:**

The Phenols values dropped from 0.20 mg/L (Table 5) in the inlet waste water to 0.03 mg/L (Table 6) in the outlet treated water. Comparing this result with the Chinese Standards and the Sudanese Standards in (Table 11 and 12), the maximum permissible limit of Phenols is 0.50 mg/L. So the Phenols values in the outlet treated water are compatible with the Chinese standards and Sudanese Standards for water quality.

For comparison with the Chinese and Sudanese Standards, Table (13) shows the outlet values determined for pH, sulphide, nitrogen and ammonia, chemical oxygen demand (COD), Oil and grease, total suspended solid (TSS), biological oxygen demand (BOD) and phenols.

Table (13). The outlet wastewater values determined for pH, Sulphide, Nitrogen and Ammonia , COD, Oil and Grease, TSS, BOD and Phenols for comparison with the Chinese and the Sudanese Standards.

**6.6.9. Management of environmental hazards produced by wastewater pollutants:**

A wastewater plant was added at Khartoum Refinery in order to treat the wastewater for reuse in industrial or other activities. Also, the treatment protects surface and underground water from pollution.

Pollutants such as mineral oil, pH, total suspended solids (TSS), nitrogen and ammonia, sulphides and chemical oxygen demand (COD) are monitored daily. The biological oxygen demand (BOD) is monitored bi- weekly by the Refinery wastewater analysis plant and by the Health Safety Environment (HSE) laboratories. Mechanical, chemical and biological means are used in the wastewater treatment plant to decrease the pollutants to the minimum possible level.


**Figure 6.1: Analytical equipment–Petroleum Central Laboratories-Sudan-Khartoum.**

**Table 6.1. Sudanese Limit of Liquid Waste from Petroleum Refining (Ministry of Energy and Mining, Regulations for protection of the environment in the petroleum industry, 2014).**

| Parameter | Maximum limit | |
|---|---|---|
| pH value at 25°C | 6-9 | |
| Sulphide | 1 | (mg/L) |
| Nitrogen and Ammonia | 15 | (mg/L) |

| | | |
|---|---|---|
| Chemical oxygen demand (COD) | 100 | (mg/L) |
| Oil and grease | 10 | (mg/L) |
| Total suspended solids (TSS) | 70 | (mg/L) |
| Biological oxygen demand ( BOD) | 30 | (mg/L) |
| Phenols | 0.50 | (mg/L) |

**Table 6.2. Chinese standards used for wastewater treatment (Khartoum Refinery Company, 2014):**

| Parameter | Maximum limit | |
|---|---|---|
| pH value at 25°C | 6-9 | |
| Sulphide | 1 | (mg/L) |
| Nitrogen and Ammonia | 10 | (mg/L) |
| Chemical oxygen demand (COD) | 150 | (mg/L) |
| Oil and grease | 10 | (mg/L) |
| Total suspended solids (TSS) | 30 | (mg/L) |
| Biological oxygen demand ( BOD) | 30 | (mg/L) |
| Phenols | 0.50 | (mg/L) |

**Table 6.3. Evaporation pond dimensions and activity volumes**

| | | |
|---|---|---|
| Area of pond | 650x420 | m2 |
| Depth | 2.2 | m |
| Pre-treatment effluent | 460 | m3/h |
| Daily discharge | 11000 | m3. |
| Estimated evaporation area | 800000 . | m2. |
| Estimated evaporation loss | 6800 | m3/day |
| Daily excess water | 4200 | m3 |

**Table 6.4. The outlet wastewater values determined for pH, Sulphide, Nitrogen and Ammonia, COD, Oil and Grease, TSS, BOD and Phenols for comparison with the Chinese and the Sudanese Standards.**

| Parameter | Results | Maximum limit in Chinese standards | Maximum limit in Sudanese Standards |
|---|---|---|---|
| pH value at 25°C | 4.57 | 6-9 | 6-9 |
| Sulphide | 0.025 mg/L | 1 (mg/L) | 1 (mg/L) |
| Nitrogen and Ammonia | 9.96 mg/L | 15 (mg/L) | 10 (mg/L) |
| Chemical oxygen demand (COD) | 327.00 mg/L | 100 (mg/L) | 150 (mg/L) |
| Oil and grease | 10.00 mg/L | 10 (mg/L) | 10 (mg/L) |
| Total suspended solids (TSS) | 32.00 mg/L | 70 (mg/L) | 30 (mg/L) |
| Biological oxygen demand ( BOD) | 12.00 mg/L | 30 (mg/L) | 30 (mg/L) |
| Phenols | 00.03 mg/L | 0.50 (mg/L) | 0.50(mg/L) |

**Table 6.5. Results of the inlet wastewater analysis**

| Parameter | Test Method | Unit | Result |
|---|---|---|---|
| pH value at 25c | APHA 4500 PH | | 4.57 |
| Sulphide | HACH 8131 | µg/L | 25.00 |
| Nitrogen and Ammonia | HACH 8038 | mg/L | 9.96 |
| COD | HACH 8000 | mg/L | 327.00 |
| Oil and grease | APHA 5520 D | mg/L | 10.00 |
| Total suspended solids | APHA 2540D | mg/L | 32.00 |
| BOD | APHA- 5210B | mg/L | 12.00 |
| Phenols | HACH -8047 | mg/L | .030 |

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**APENDIX**

**The methods used in testing refinery wastewater in Petroluem Central laboratory, Khartoum**

**The Waste Water Analyses Test Methods**

1. *The Analysis of the Sulphide by Methylene Blue Method:*

The analysis is fully computerized. First the HASH PROGRAM is selected and the number 3500 for the sulphide analysis is entered and the ENTER key is pressed so that the display showed: HACH PROGRAM: 3500 Sulphide, with the wavelength (λ ), 665nm, is automatically selected. 25 mL from the sample were measured into a sample cell and 25 mL of deionized water were transferred into a second sample cell (the blank). To each cell 1.0 ml of Sulphide 1 Reagent was added and whirled in order to mix. 1.0 ml of Sulphide 2 Reagent was added to each cell. Then, A5-minute reaction period was stored by pressing the soft key under START TIMER. When the timer beeped, the blank sample was placed in the cell holder and the light shield closed. Then the soft key under ZERO was pressed and the display showed 0μg/L S2-. Finally, the prepared sample was placed in the cell holder and the light shield closed. The result in μg/L Sulphide (or chosen units) was taken.

2. *The analysis of the Nitrogen, Ammonia by the Nessler Method*

The soft key under HACH PROGRAM was pressed and the stored program for low range ammonia nitrogen (NH3-N) was selected by pressing the number 2400 and the ENTER key was pressed so that the display showed: HACH PROGRAM: 2400N, Ammonia Nessler, with the wavelength (λ), 425nm, is automatically selected. A 25-mL mixing graduated cylinder was filled (the prepared sample). Another 25 ml mixing graduated cylinder was filled with deionized water (The blank). Three drops of polyvinyl Alcohol Dispersing Agent were added to each cylinder by holding the dropping bottle vertically. The cylinder was inverted several times to ensure proper mixing. Then 1.0 ml of Nessler Reagent was pipetted into each cylinder Stopper and inverted several times to ensure proper mixing. Next, the soft key under START TIMER was pressed so that a one-minute reaction period began. Each solution was poured into a sample cell. When the timer beeped the blank sample was placed into the cell holder and the light shield closed. Then the soft key under ZERO was pressed and the display showed: 0.000mg/L NH3. Finally, the prepared sample was placed into the cell holder then the light shield closed. The results in mg/L ammonia expressed as nitrogen (NH3-N) (or chosen units) were taken.

*3. The analysis of the Phenols:*

The analysis is also fully computerized. First the HACH PROGRAM was selected and the number 2900 for phenols analyses was entered and the ENTER key was pressed. The display showed HACH PROGRAM 2900 phenols, with the wavelength (λ) 460 nm is automatically selected. Then 300 mL from the deionized water were measured into 500mL graduated cylinder and the measured deionized water was transferred into a 500ml separatory funnel (the blank). 300mL of sample were measured into a 500 ml graduated cylinder. Then the prepared sample was transferred into another 500 ml separatry funnel and 5ml of hardness 1 buffer to each separatory funnel were added and stoppard and shaked in order to mix. Then the contents of one phenol reagent powder pillow were added to each separatory funnel, stoppard and shaked in order to dissolve. Then the contents of one phenol 2 reagent powder pillows were added to each separatory funnel, stoppard and shaked in order to dissolve. 30 ml of chloroform were added to each separatory funnel, stoppard. Then each funnel was inverted and temporarily vent, and vigorously shaked for 30 seconds. Then the stoppers was removed in order to allow both funnels to stand until the chloroform settles to the bottom of the funnel. A large pea-sized cotton plug was inserted into the delivery tube of each funnel. The chloroform layers were drained into separate sample cells (one for the blank and one for each sample).Then the blank sample was placed into the cell holder and the light shield closed. Then the soft key under ZERO was pressed and the display showed: 0.000 mg/L phenol. Finally, the prepared sample was placed into the cell holder and the light shield closed. The result in mg/L phenols was taken.

*4. Determination of the Total Suspended Solids:*

A disk with its wrinkled side up was inserted into the filtration apparatus under vacuum and washed with three successive 20-mL portions of reagent-grade water. The suction was continued in order to remove all traces of water. Then the vacuum was turned off, and the washings discarded. The filter was from the filtration apparatus and transferred into an inert aluminum weighing dish. The crucible and filter were then dried in an oven at 103 to 105 ºC for 1 h. To measure the volatiles the crucible was ignited at 550 ºC for15 min in a muffle furnace, then cooled in a desiccator and weighed. The cycle of drying, igniting, cooling, desiccating, and weighing was repeated until a constant weight is obtained or until the weight change is less than 4% of the previous weight or about 0.5 mg, whichever less, and the crucible was stored in a desiccator until needed.

A sample volume to yield between 2.5 and 200 mg was chosen and the residue dried residue. If the volume filtered fails to meet the minimum yield, the sample volume was increased to 1L. If complete filtration takes more than 10 min, then the filter diameter was increased or the sample volume decreased.

Sample analysis: Assemble filtering apparatus and being suction. The filter was wetted with a small volume of reagent and the sample was stirred with a magnetic stirrer at such a speed to shear larger particles, (if present) to obtain a more uniform (preferably homogeneous) particle size. Centrifugal force may separate point of sample with drawal is varied. While stirring, pipet a meas-samples, piped from the approximate midpoint of container but not in vortex. A point both mid depth and midway between wall in vortex was chosen. The filter was washed with three successive 10 ml volumes of reagent-grade water and allowed to drain completely after each washings. Suction was continued for about 3 mints after filtration is complete. Samples with high dissolved solids may require additional washings. The filter was then carefully removed from the filtration apparatus and transferred to an aluminum weighing dish as a support. Alternatively, the crucible and filter were removed complete from the crucible adapter. If a Gooch crucible was used the sample was dried for at least 1 h at 103Coto 105 C$^{o}$ in an oven and cooled in a desiccator to weighing temperature. The cycle of drying, cooling, desiccating and weighing was repeated until a constant weight is obtained or until the weight change is less than 4% of the previous weight or within 0.5 mg, whichever is less. About 10% of all samples were analyzed twice. Duplicate determinations should agree within 5% of their average weight if the volatile solids are to be determined. The residue was analyzed according to the programme 2540E.

**Calculations:**

total suspended solids mg / L = (A-B) X 1000 / sample volume (mL)

where:

A(mg) = weight of filter + dried residue, and

B(mg) = weight of filter.

5. *pH value:*

Instrument calibration: In each case follow manufacture's instructions for pH meter and for storage and preparation of electrodes for use. Solutions for short-term storage of electrodes have conductivity greater than 4000 µmhos /cm. was recommended. Tap water is a better subsume than distilled water but pH 4 buffers is the best for the single glass electrode and saturated KCL was preferred for a calomel and AG/AGCL reference electrode. Saturated KCL is the preferred solution for a combination electrode. Then electrodes wet by returning them were kept to storage solution whenever pH meter is not in use.

Before use, electrodes from storage solution were removed, rinsed and blotted dry with a soft tissue then placed in initial buffer solution and that is the potential point. Next a second buffer within 2 pH units of sample pH was selected and the sample and buffer were brought to the room temperature, such as 25ºC, or the temperature of a fresh sample. The electrodes were removed from first buffer, rinsed thoroughly with distilled water, blotted dry and immersed in second buffer. The temperature of measurement was recorded and adjusted temperature dial on meter so that meter indicates pH value of buffer at test temperature.

The pH value listed in the tables was used for the buffer used at the test temperature. Then electrodes from second buffer were removed , rinsed thoroughly with distilled water and dried electrodes as indicated above and immersed in a third buffer below pH 10, approximately 3pH units different from the second; when only occasional pH measurements were made and the instrument was stable , standardized less frequently.

Sample analysis: equilibrium between electrodes was established and stirred sample to insure homogeneity; conditioned electrodes after cleaning by dipped them into sample for 1 min. blotted dry, immersed in a fresh portion of the same sample, and read pH.

6. *Chemical Oxygen Demand (COD)* determination by Calorimetric Measurement Method ( for 0 to 40 mg/L range).

100 mL of sample were homogenized for 30 seconds in a blender. The COD Reactor was turned on preheated to 150 ºC. The plastic shield was placed in front of the reactor. The cap of the COD Digestion Reagent vial was removed for the appropriate range and held at 45-degree angle in order to pipette 2.00mL (0.2 mL) for the 0 TO 15,000 mg/L range) of sample into the vial. The cap of the vial was replaced tightly and the COD vial was

rinsed with deionized water and wiped with a clean paper towel. Next the vial was held by the cap and over a sink, inverted gently several times to mix the contents and replaced in the preheated COD reactor. A blank sample was prepared by repeating steps 3 to 6, substituting 2.00 mL (0.2 mL for the 0 to 15,000 mg/L range) with deionized water and placed the blank in the COD reactor. The vials were then heated for 2 hours. Afterwords, the reactor was turned off and the vials were left for 20 minutes to cool to 120 ºC or less, inverted several times while still warm and finally placed into a rack to cool to room temperature.

The sample was digestion described for the "Oxygen Demand determination. The key under HACH PROGRAM was pressed and the program number for ultra low range COD was selected by pressing 2700 with the numeric keys followed by ENTER. The display showed: HACH PROGRAM: 2700 COD, ULR with the wavelength (λ,350 nm) was automatically selected. Then the N Tube Adapter was inserted into the sample module by sliding it under the thumb screw into the alignment grooves and then fastened with the thumb screw. The outer surface of the blank was cleaned with a towel, and placed into the adapter with the Hach logo facing the front of the instrument and the light shield closed. The soft key under ZERO was pressed and the display showed: 0.00mg/L COD. The outer surface of the sample vial with a towel. Finally, the sample vial was placed into the adapter with the Hach logo facing the front of the instrument and the light shield closed. The results in mg/L COD (or chosen units) was then displayed.

7. *Determination of Oil and Grease:*

The sample bottle was marked at the water meniscus. Then 1:1 HCL or1:1 $H_2SO_4$ was added to pH 2 or lower (5ml for 1L). Next the sample was transferred to a separatory funnel by liquid funnel and the sample bottle was rinsed with 30 mL extracting solvent and the solvent washings were added to the separatory funnel. The bottle was shaken vigorously for 2 min until the layers separated. The aqueous layer and a little amount of organic layer were drained into the original sample container. The centrifuged material was transferred into an appropriate separatory funnel and the solvent layer was drained twice through a funnel with a filter paper with an additional 10g of $Na_2SO_4$ solvent- rinsed. Then aqueous layers and any remaining emulsion or solids were added together into a separator funnel. Then twice 30ml solvent was extracted each time. The solvent in the flask was distilled in a water bath at 85ºC for either solvent system. The solvent was collected in an ice-bath-cooled receiver. After the visible solvent condensation stops, the flask was removed from the water bath. Still at 85ºC, air was drawn through the flask for 15 min with an applied vacuum for the last 1 min. The sample was then cooled in a desiccator for at least 30 min and weighed. Finally, the sample volume was calculated by the difference from the initial volume.

8. *Determination of the Biological Oxygen Demand (BOD)*

The water sample was heated to within 20◌ C of its incubation temperature (typically200◌C,680F). Then a clean graduated cylinder was used to pour the correct sample volume into a BOD Trak sample bottle. The sample dilutions for more information on BOD range selection.

**Table 6.6. Selection of Sample Volume**

| BOD Range(mg/L) | Required Volume (mL) |
|---|---|
| 0-35 | 420 |
| 0-70 | 355 |
| 0-350 | 160 |
| 0-700 | 95 |

Next a 3.8-cm (11/2-inch) magnetic stir bar was placed in each sample bottle. The contents of one BOD Nutrient Buffer Pillow were added to each bottle for optimum bacteria growth. Then Stopcock Grease was applied to the seal lip of each bottle and to the top of each seal cup. After that a seal cup was placed onto the neck of each bottle. Then the funnel was used and the contents of one Lithium Hydroxide powder pillow was added to each seal cup .The lithium hydroxide particles were not allowed to fall into the sample. The bottle was placed on the chassis of the BOD Trak. The appropriate tube was connected to the sample bottle and the cap was firmly tightened. Each tube was tagged with the channel number, and the channel number setup was reflected on the control panel. The instrument was placed in the incubator and started (The electrical plug was connected and turned on). All stir bars were rotating. If a stir bar slided to the side of the bottle off the unit it was gently replaced. The channel should not be started until the stir bar was rotating properly. To select a test duration, the<(left) and the>(right) arrow keys were pressed simultaneously and held until the time menu appears and theCHANNEL6 key was pressed to activate the test length parameter. Then the arrow keys were used to choose a 5-,7-,or10- day test (test length is shown on the last line of the screen) .The OFF button was pressed to save the selections and exit the menu. To start a test the channel number corresponding to the bottle was pressed and then the ON key. A menu for selecting the BOD range was displayed. For 0-350 mg/L range, the>(right) key was pressed once . For 1-700mg/L the >key was pressed for a second time. For 0-35 mg/L range, the <(left)key was pressed once. For 0-70 mg/L the<key was pressed for a second time. The ON key was pressed and held to start a test. A graph was displayed .To cancel a test, press OFF. The BOD results were read directly from the BOD Trak display by pressing the key corresponding to each sample. Finally, a brush and hot soapy water were used to clean all the bottles, stir bar, and seal cups and they were then rinsed thoroughly with distilled water.

# CHAPTER SEVEN

# ANALYSING FIVE GLOBAL SUSTAINABLE ASSESSMENT METHODS IN SUSTAINABLE BUILDINGS TO EMERGE BY NEW PRINCIPLES FOR HOT -DRY CLIMATE (SEBAM), WITH FOCUS ON GREATER KHARTOUM

# Analysing Five Global sustainable assessment methods in sustainable buildings to emerge by new principles for hot -dry climate (SEBAM), with focus on Greater Khartoum


## 7.1. Abstract

Several assessment programs have been developed worldwide on the environmental and energy effect of buildings. The aim of this study is to identify the main and subcategories of sustainable design. The researcher has investigated and compared four global building rating systems, namely leadership in Energy and Environmental Design BREEAM UK, (LEED), Emirates Green Building Rating System (ESTIDAMA), Global Sustainability assessment System (GSAS) in Qatar and Australian green Star rating system (AGBC rating system), in Australia. This paper focuses mainly on their processes, contents, similarities and differences, processes, evaluation, their development and wither these systems are applicable to all environments.

The paper outlined five main categories developed by these global rating systems being: Sustainable site, indoor environmental quality, materials, water efficiency, power supply system and innovations subcategories were added according to their social, cultural, economic and legislations conditions.

The paper recommended four main categories suitable to hot -dry climate.



*Keywords*: BREEAM system, LEED system, ESTIDAMA system, GSAS system and Australia green star system, similarities and differences categories, categories for hot dry climate.


## 7.2. Introduction

### 7.2.1. Sustainable-eco-building methods

Sustainability has widely spread globally, regionally and has recently started locally. The industrial sectors, including the building sector, have started to recognize the environmental impact of their activities; starting in the 1990s in Sudan. Moreover, significant changes were needed to mitigate the environmental impact of the building sector with a focus on the buildings' design, built and operated. One of the key drivers of this transformation was public policy, and another was the growing market demand for environmentally sound products and services. Thus, in order to reduce environmental impacts, a yardstick for measuring environmental performance was needed (Hapio, 2008). The environmental rating systems have been added recently since 1999. The first system to be established was the BREEAM in 1999 and it was followed by many others such as LEED, which was started in the USA, in the year 2002.

### 7.2.2. Definition of methods

Environmental rating systems, such as the Leadership in Energy and Environmental Design (LEED), is defined as:

'*Rating systems are groups of requirements for projects that want to achieve LEED certification. Each group is geared toward the unique needs of a project or building type*' (Council, 2014).

### 7.2.3. Building rating systems

Rating systems have become a universal trend where many countries around the world are increasingly adopting a rating system for building constructions. Currently, there are about 40 rating systems around the world. Figure 4.2 presents some global systems around the world. The pioneering BREEAM system is an international system for evaluating sustainable green buildings and applicable in all types of climates; followed by GREEN GLOBS in Canada in 2000, LEED in the USA in 2002, CASBEE in Japan in 2002, and Green Star in Australia in 2008. Further, the rating systems are spread widely through the European continent, Asia, and America; and recently were introduced in Africa by the Green Building Councils or NGOs. Table 1 and Figure 1 provide a summary of some global systems around the world. Figure 1 shows rating systems around the world while Table 1 shows summary of the rating system around the world.

### 7.2.4. Comparison between five global systems

The aim of this comparison is to outline the main categories developed by these global rating systems. These are the sustainable site, indoor environmental quality, materials, water efficiency, power supply systems, and innovations. Sub categories were added in accordance with their social, cultural, economic and legislative conditions.

#### 7.2.5. The previous studies

A study was presented by WAN (2014) in a paper on Energy Star, Green Globes, BREEAM, CASBEE, NABERS, High-quality environmental standards, HK BEAM, Green Mark Scheme, GB Tools, and GBI. The paper discussed each system's process, content, main categories, and issues and rationalized the GBI system in Malaysia. Second, a study was conducted by Fenner (2008) that discussed LEED and BREEAM; tackling the main categories, rating methods, assessment costs, and accessibility vision for the future. Third, Chaimosy (2006) provided analysis of the development of LEED and Green Globes; and analysed the Life Cycle Analysis (LCA), providing a preliminary assessment of its environmental relevance. Fourth, Fowler (2006) provided a report that deeply analysed LEED, CASBEE, GB Tools and Green Globes. The report revised the methods' usability, durability, and main categories. Fifth, a paper was written by Haapio (2007) that studied the existing environmental assessment tools and the main categories. The paper also assessed buildings and users of the tools.

The researcher conducted a comparison between the five selected sustainable building assessment methods in order to determine common principles between them. These global systems are as follows: Leadership in Energy and Environmental Design (LEED), the Environmental Assessment Methods (BREEAM), Green Star Rating System of the Green Building Council of Australia, Qatar Global Sustainability Assessment System (GSAS), ESTIDAMA Environmental Assessment System, and Saudi Green Building Forum (SGBF).

#### 7.2.6. Objectives of the comparison

1) To identify the definition of the rating system.
2) To introduce the international sustainable rating systems for purposes of discussion in the study: ESTIDAM and GSAS, LEED V4, Australia Green Star Building Rating System (AGB) and BREEAM.
3) To study and discuss the systems in the process, categories, sub-issues, development, applicability, similarities and differences.
4) To assess if they are suitable for application in hot dry climates or a modified version is necessitated in the study area.

5) To give guidelines for a sustainable assessment method for hot dry climates.

### *1.1. Leadership in Energy and Environmental Design (LEED)*

LEED is an internationally recognized green building certification system. Developed by the U.S. Green Building Council (USGBC) in March 2000, LEED provides building owners and operators with a framework for identifying and implementing practical and measurable green building designs, constructions, operations and maintenance solutions (Council, 2014). Table 2 shows the main categories of LEED V4 system.

The positive point of LEED is that it has been developed since 2000 through to 2013 and has been reviewed four times, where we now find LEED 2009, LEED V3 and LEED V4. The LEED process is developed from time to time with announcements made on the USGBC.org for members who are interested to share their experience. The development process takes about six months from review 1, review 2 through to review 3. They listen to experts, professionals and users views towards improvement of the negative notes into possible positive issues. In LEED v3 the sustainable site increased from 14 points to 26 points, more challenges were added, like development density and community connectivity (5 points), alternative transportation (12 points max), storm water design (2 points max) and site development (up to 2 points). In water efficiency, they increased water use reduction from 5 points to 10 points; they added water efficient landscaping (5 points max), innovation wastewater technologies up to 2 points. In energy the total points increased from 17 points to 35 points; the main focus was on optimizing energy performance (19 points max), on site renewable energy (7 points max), enhance refrigerant management (2 points), measurement and verification (3 points max) and green power (2 points). In materials the total points increased from 13 points to 14 points; they increased the points on material reuse from 1 point to 2 points. The total points on indoor environmental quality remained the same at 15 points. Innovation increased from 5 points to 6 points.

Haselbach (2008) presented an introduction to sustainable construction and discussed the LEED system and its principles. Council (1996) discussed the main issues of environmentally sustainable development.

In addition, LEED released V4 in July 2013. Malin (2013) discussed in their report the new concepts in LEED V4 and stated that LEED V4 added integrative design processes. LEED V4 added rainwater management in sustainable site category and provided reduction in light pollution. In addition, it added building envelop commissioning, green power and carbon offsets. They also added building life assessment, biomass raw materials, response to Mining, Health product, Measuring of VOCs. In the indoor environment, special day light autonomy and acoustic performance were added. LEED V4 was finalized after the fifth public comments through the period from fall 2012 to fall 2013.

From the above analysis, we can conclude that the rating system is a developing system. LEED was developed from 2000 to 2017 and they announced four versions during that period. These improvements depend on the best practices from users and experts. In each version, we have more challenges, and the total points are increased to achieve a higher certification standard. It also contains sub issues that help in managing a certain local and global problem; an example of local problems is the design of storm water within the sustainable site category; and examples for global problems that influence the local environment are heat island effect, smoke control, and energy performance optimization.

### *1.2. The environmental assessment methods (BREEAM)*

BREEAM for master planning projects, infrastructure and buildings. It recognises and reflects the value in higher performing assets across the built environment lifecycle, from new construction to in-use and refurbishment. BREEAM was one of the 10 global building rating systems published in a paper by Science (2009), was created in 1990 for the UK building market and is administered by the BRE Global Sustainability Board, which oversees BRE Global guides, publications, standards and certification programs (BREEAM, 2014). BREEAM has the following goals: understanding and mitigating the impacts of buildings on the environment; enable buildings to be recognized according to their environmental benefits; provide a credible, environmental label for buildings; stimulate demand for sustainable buildings (BREEAM, 2014).

In addition, BREEAM has four assessment tools that can be used at different stages of a building's life cycle. BREEAM Design and Procurement (D&P) can be used during the designing stage of a building renovation or for a new building or extension project. The Post Construction Review (PCR) is carried out once the construction is complete to verify the D&P assessment. The Fit-Out assessment is employed during major renovations of existing buildings and a Management and Operation (M&O) assessment evaluates the performance of a building during its operation (Saunders 2008).

BREEAM method of assessment: BREEAM schemes award credits for each section, which are then summed and weighted according to the section weight. Credits are awarded in 10 categories for meeting a series of performance criteria that, if complied with, would reduce the building's negative environmental impact and increase its environmental benefits. The total number of credits awarded is 114 points in each category is multiplied by an environmental weighting factor the category scores are then added together to produce a single overall score on a scale of Pass, Good, Very Good, Excellent and Outstanding. A star rating from 1 to 5 also is provided (Saunders, 2008).

Energy, Management, site management and procurement, health and well-being: indoor, transport, Water, Materials, Waste, Land Use, Pollution and Ecology. Table 3 shows BREEAM weight system and certificate levels.

The positive for BREEAM is providing a program to address the environmental impact of buildings lies in better management and improvement of the existing building stock. BREEAM In-Use is a scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings. The main goals of this program are as follows; reduce operational costs; enhance the value and marketability of property assets; give a transparent platform for negotiating building improvements with landlords and owners; provide a route to comply compliance with environmental legislation and standards; give greater concern and engage with staff in implementing sustainable business practices; provide opportunities to improve staff satisfaction with the working environment and increase the potential for significant improvements in productivity. BREEAM is developed by clients, planners, development agencies, funders and developers (BREEAM, 2019).

### *1.3. Green Star Rating System of the Green Building Council of Australia*

Green Star is a comprehensive, national, voluntary environmental rating scheme that evaluates the environmental design and achievements of buildings. It started in 2002 and is developed by the Green Building Council of Australia. Their aims are: to establish a common understanding; to set a standard for measuring sustainability of green buildings; promote integrated whole-building design; recognize environmental leadership; identify building life-cycle impacts; and raise awareness of green building benefits. Green Star covers several categories that assess the environmental impact as a direct consequence of a project's site selection, design, construction and maintenance. The Green Star Rating System of Australia announced the following schemes: Green Star Multi Unit Residential V1, Green Star Healthcare V1, Green Star Retail Centre V1, Green Star Education V1, and Green Star Office Design V2 and V3. The nine categories included within all Green

Star rating tools are: management, indoor environment (BREEAM, 2019) energy, transport, water, materials, land use, ecology, emissions and innovation (Australia, 2013). Table 31 shows the Australian Green Star rating system and points for each category. Table 4 shows the green Star Rating System.

Green Star rating system assessment method: A GBCA case manager is assigned to support the project team through the assessment process. Once the applicant signs the necessary agreements, the project team submits appropriate documentation for the first round. If unsuccessful, the submission is returned with guidance on what needs to be done before resubmission. If the review is successful, an assessment panel will be convened. Projects that are awarded one to three stars may not be certified, but those awarded with four or more stars may be certified and are recognized as follows

i. 4 Star Green Star Certified Rating (score of 54 to 59) - Best Practice
ii. 5 Star Green Star Certified Rating (score of 60 to 74) - Australian Excellence
iii. 6 Star Green Star Certified Rating (score of 75 to 100) - World Leadership (GBCA. 2009)

Each rating tool includes a number of credits in nine categories. Within the credits, points may be awarded for each credit criteria. The nine categories include management, energy, indoor environmental quality, transport, water, materials, land use and ecology, emissions and innovation. Each rating tool also applies environmental weightings for each of these categories as may be appropriate for that tool or a geographic area(s) (GBCA, 2009; Australia, 2013).

### *1.4. Qatar Global Sustainability Assessment System (GSAS)*

The Global Sustainability Assessment System (GSAS) is the first of its kind, performance-based sustainability rating system in the MENA region that started in 2007. It is developed by the Gulf Organization for R&D in collaboration with T.C. Chan Centre at the University of Pennsylvania – USA. The assessment system aims at creating a sustainable urban environment to reduce environmental impacts while satisfying local community needs.

The aims of GSAS rating system: First, the environmental benefits, which include the enhancement and conservation of flora/fauna, biodiversity and ecosystems; conservation and restoration of natural and non-renewable resources; improvement of air, land and water quality; increase of energy efficiency while reducing greenhouse gas emissions; and reduction of waste production. Second, the economic benefits, which consist of reductions in operating and maintenance costs; creation of new opportunities and markets for green products and services; and improvement in occupant productivity, faster occupancy rates and lower turnover rates. Third, the social benefits, which include enhancement of human comfort and health; reduction in strain on local infrastructure; improvement of life quality; and preservation of cultural identity.

GSAS method of assessment: The criteria of GSAS are divided into eight categories (different weights), each with a direct impact on environmental stress mitigation and measures a different aspect of the project's environmental impact. The main categories are: Urban community, site, energy, water, materials, indoor environmental quality, culture and economic value and management operation. At present, there are thousands of buildings which are designed in accordance with this system. Table 5 shows GSAS main categories and the total weight for each category.

Diar (2010) noted that the vital role played by the NGOs is to encourage organizations to act sustainably and raise awareness of green issues in Qater. The positive for GSAS is that it allows complete flexibility in future 2 shows GSAS main categories and weight system. Fig. 2: Shows GSAS main categories and its weighing system expansions and modifications, as well as for the seamless integration between Qatar specific requirements and sustainable goals. The system takes advantage of the best features of the rating systems available worldwide with a focus on the needs and impacts on Qatar and the surrounding regions. The GSAS rating system is applicable to all building types and projects. Alhorr (2014) presented a workshop about the deployment of GSAS in GCC construction; industry challenges and opportunities to apply GSAS regionally. He stated that GSAS started by studying 40 global rating systems and focused on the basic study of six systems, which helped in developing their own local system.

### *1.5. ESTIDAMA Environmental Assessment System*

ESTIDAMA, which is the Arabic term for sustainability, was established in 2008 by The Abu Dhabi Urban Planning Council (UPC); announcing ESTIDAMA V1 in 2010. It is recognized internationally for large-scale sustainable urban planning and rapid growth. Promoting thoughtful and responsible development while creating a balanced society on four equal pillars of sustainability: environmental, economic, social, and cultural. 4

*The goal of ESTIDAMA* is to preserve and enrich Abu Dhabi's physical and cultural identity, while creating an always improving quality of life for its residents focusing on the rapidly changing built environment. All new projects must achieve a minimum 1 Pearl rating to receive approval from the planning and permitting authorities. Government funded buildings must achieve a minimum 2 Pearl rating.

*ESTIDAMA Method of assessment*: ESTIDAMA has the Pearl Rating system that is also a point-based system, awarding project points for different credits that are grouped under several general categories. Points are added up to a final rating which ranges from one pearl to five pearls system. The pearl process passes through four stages: pearl design, pearl construction and the pearls operational system. Table 6 shows ESTIDAMA's main categories and the total points of each main category. Table 6 shows ESTIDAMA main categories and the total points of each main category

The positive point is ESTIDAMA itself is a part plan of Abu Dhabi 2030 that encourages sustainable growth, protection of the natural environment of the sensitive coastal and desert ecologies (Council, 2010).

### *1.6. Saudi Green Building Forum (SGBF)*

Saudi Green Buildings forum (SGBF) started on 05/10/2010. The Saudi Green forum's workshops, conferences and exhibitions emerged from the initiative lead by Faisal Al Fadal. Partners and the private sector were permitted to hold conferences, in accordance with the royal instruction given to the high commissioner and the approval of the Ministry of Commerce and Industry (SGBF, 2010).

*The aims of SGBF* are to facilitate the exchange of ideas, scientific production technologies and professional interests in the field of the forum between institutions and relevant bodies within and outside the Kingdom; to contribute to the development of standards of practice and professional projects in relevant disciplines; to participate in monitoring their performance and maintenance; to contribute to raising the level of among the public.

*The method of SGBF* main categories of SGBF are: development site, transportations, atmosphere, indoor environmental quality, living environmental quality, water, energy, material, innovation and culture. SGBF uses points for evaluation (King Fahad Universit).

### *1.7. Sustainable Eco Building Assessment Method Applied in Residential Buildings in Greater Khartoum*

This system was emerged as a result in PhD research, faculty of Architecture, Graduate College in Khartoum University, was published in July 2019.

The system consist of eight main categories, Sustainable site, Indoor Environmental Quality, outdoor environmental Quality, Building Form, Energy efficiency, Water Efficiency, Building Material, Environmental design process. The system consist of 125 sub issues, evaluated by points and have scale of pass, good, very good and Excellent (Abdelmoneim, H., 2019) and (Abdelmoneim, H., 2020).

## 7.3. The methodology

The methodology begins by literature review of the previous studies to study and compare between four international sustainable assessment methods which are BREEAM, LEED V4, AUSTRALIA GREEN STAR BUILDING RATING SYSTEM (AGB), ESTIDAM and QSAS. The documents are available through their websites. Then; method of presentation is presented in tables and figures to identify the main categories of each system, sub issues, process, method of evaluation, and the certificate levels. This has been followed by; deep analysis and discussion of the main categories: Sustainable site, indoor environment, energy, water and materials to identify the similarities and differences. The second part of the study focuses on studying the additional categories suitable to hot dry climate. The study outlines the main categories which should be implemented by any international sustainable building rating system with respect to environmental, social, economic aspects and identifying the additional categories suitable to hot dry climate.

## 7.4. The Results and Findings

I. The comparison shows that there are similar Categories shared between the four global rating systems BREEAM, , LEED, Australia Green Star rating system, ESTIDAMA and QSAS, namely: Sustainable Site, Indoor environmental quality, Energy, water material and innovation.

II. As well; there are additional categories introduced by these global systems: Australia green star system provided new additional categories, which are management, transportation and land ecology. ESTIDAMA added: Urban community, Culture and economic value, integrated development process. QSAS: Culture and economic value.

The system added these new categories aiming to connect the design with local culture, economic and local community and local environment.

III. There are similarities and differentiations observed in each Category existing in the main issues, and which are attributed to the deference in location, environmental conditions, natural resources, culture, and economic aspects.

IV. The total points of BREEAM are (140 points), LEED v4 are (110 points), Australia (100 points), ESTIDAMA (159 points), and QSAS has (100, 500, 1000 points). BREEAM uses points and star system, LEED uses points in evaluation and the categorization ranges from silver, Gold, Platinum. GBA uses Star Rating System and the categorization range from one star to six stars, ESTIDAMA uses Pearl rating system and the categorization range from one pearl to six pearl and QSAS uses star rating system.

V. Each system has a certain process identified in their website; BREEAM has several steps in Design, construction and Operation. LEED certification involves five primary steps: Determine which rating system used, Registration of project, Submission of certification application and paying a certification review, await the application review, receive the certification decision. Green Star Certification uses a formal process which involves a project using a Green Star rating tool to guide the design or construction process during which documentation. The Green Building Council of Australia will commission a panel of third-party Certified Assessors to validate the documentation and there are two rounds of Assessment available to a project for which to achieve validation of credits claimed. The Development Review Process has been introduced by Dhabi Urban Planning Council (UPC) to provide a streamline process for reviewing development proposals. In QSAS the process starts by submission of the project, preliminary review, appealing of the certifying body's decision, final review and Certification.

VI. Sustainable site similarities are: heat island effect and -site development; on the other hand, the differences in LEED V4 site assessment, site development, open space, rain water management, heat island reduction and light pollution reduction. QSAS has added more additional issues in site category like Ecological Value of Land; ESTIDAMA and Australia rating system: does not have sustainable site.

VII. In the Indoor Environment the similarities increase: Ventilation Construction, Low-Emitting Materials, Composite Wood & Agrifiber Products, Daylight & Views, Daylight 75% of Spaces, Thermal Comfort. On the other hand; in LEED V4 the differences minimize: indoor performance, environmental tobacco control, enhance indoor air quality control, low emitting materials, thermal comfort, day lighting, views and acoustic performance. Australia rating system added HVAC system and pollutants. QSAS added Monitoring air temperature and quality and adjusting or calibrating as appropriate and Mechanical ventilation.

VIII. In Energy the similarities are: Optimize Energy Performance, On-Site Renewable Energy, Measurement & verification green power. On the other hand; the differences in LEED V4 are: Fundamental commissioning and verification, minimum energy performance, energy metering, renewable energy, refrigerant management and green power. Australia rating system added HVAC System Simulations, building Envelope, A/C Pumping, and Modelling Information. ESTIDAMA added Community Energy Strategy, Building Energy Guidelines, Energy monitoring and reporting and Community Strategies for Passive Cooling, QSAS added Energy Demand Performance, Energy Delivery Performance, and Fossil Fuel Conservation.

IX. In water the similarities are: water Efficient Landscaping, Water Use Reduction. On the other hand; the differences in LEED V4 are: outdoor water use reduction, indoor water use reduction, water metering and cooling tower water use. Australia rating system added solar collectors, Hot water rating load, Measurements, water reuse. ESTIDAMA added Community Water Strategy, Building Water Guidelines and Water Monitoring. QSAS: added Water Consumption.

X. In materials the similarities are: Construction Waste Management, Materials Reuse, Recycled Content, Regional Materials, and Certified Wood. On the other hand; the differences in LEED V4 are: construction waste management planning, building life cycle analysis, environmental products, use of raw materials, Australia rating system added Eco content, durability, environmental management system. ESTIDAMA added Basic Construction Waste Management, Reused or Certified Timber. QSAS added recycling content and regional building materials.

XI. The logic of rating system is open mind for all specialists who can share solutions by their experience and specialization.

XII. The conclusion arrived at through this analysis, is that rating system is an ever- evolving process, and its improvement depends on the best practice of users and experts. In each version we have more challenges and the total points are increased to achieve a higher certificate.

XIII. As a matter of fact; it contains sub issues that help in managing a certain local and global problems, for example, local problems: storm water design in Sustainable site category; and for global problems, examples are: that have an effect on the local environment heat island effect, smoke control, optimize energy performance.

XIV. By this comparison, we can fix five main categories for sustainable eco buildings, which are sustainable site, Energy, water, material, indoor environmental control.

XV. More categories, suitable to our local environmental conditions, could be added e.g.: culture, social aspect and local legislations. The issues are detailed according to our local interest and environmental problems visualized for Greater Khartoum as the case study lays in hot dry climate. The research gives a frame work for assessment method suitable to hot dry climate such as Greater Khartoum. In addion to the five basic categories: sustainable site, indoor environmental quality, water efficiency, energy efficiency and material. The research outlines the following categories:

## 7.5. The discussion

***1. The sustainable site:***

(Table 7) shows: the analysis of sustainable site between the five global systems.

The similarities in the main issues of Sustainable site category are:

- heat island effect
- site development

**The differences in the main issues of sustainable site category are:**

**I.** ***BREAM*** has added more additional issues in Site Category i.e.: Site selection, Ecological value of site and protection of ecological features, minimizing impact on existing site ecology, Enhancing site ecology, Long term impact on biodiversity.

**II.** ***LEED*** has added more additional issues in Site Category i.e.: Construction Activity Pollution Prevention, Site Selection, Development Density & Community Connectivity, Brownfield Redevelopment, Alternative Transportation, Public Transportation Access, Alternative Transportation, Bicycle Storage & Changing Rooms, Alternative Transportation, Low-Emitting & Fuel-Efficient Vehicles, Protect or Restore Habitat, Site Development, Maximize Open Space, Storm water Design, Quantity Control, Heat Island Effect, Non-Roof, Light Pollution Reduction, Green vehicles, access to quality transit, est.

III. ***Australia rating system***: They don't have sustainable site.

IV. ***QSAS***: added more additional issues in site category which are: Ecological Value of Land, Ecological Value of Land, Land Preservation, Vegetation & Shading, Water Body Preservation, Desertification, Rainwater Runoff, Landscape Amenities, Vegetation, Mix use center, Walk ability.

V. ***ESTIDAMA***: None

VI. ***SEBAM***: Study of the location, study of the building construction, study of the landscape, outdoor lighting , heat island effect control the noise, bike control, transportation control, parking cover by shed.

***2. Indoor Environmental Quality (IQE)***

Table 8: Concluded the indoor environment as follows:

***The similarities in the main issues of Indoor environment category are***: Increased Ventilation Construction, Low-Emitting Materials, Composite Wood & Agrifiber Products, Daylight & Views, Daylight 75% of Spaces, Thermal Comfort and Verification. ***The differences in the main issues of Indoor environment category are***:

I. ***BREEAM***: None

II. ***LEED***: has added more additional issues in Control indoor environment Category which are: Minimum IAQ Performance, Environmental Tobacco Smoke (ETS) Control, Outdoor Air Delivery Monitoring, Construction IAQ Management Plan, Before Occupancy, Indoor Chemical & Pollutant Source Control, Views, Illumination Levels, Acoustic Quality, Daylight, indoor construction plan, thermal comfort, quality views and acoustic performance.

III. ***Australia***: New additional points has been added which are essential for contemporary design on shopping malls, educational and office buildings: HVAC system and pollutants.

IV. ***ESTIDAMA***: None.

V. ***QSAS***: has added additional points which are: Monitoring air temperature and quality and adjusting or calibrating as appropriate, Maximizing views to the exterior for all occupants, Mechanical ventilation, Indoor Chemical & Pollutant Source Control, Illumination Levels, Acoustic Quality, Daylight.

**VI.** ***SEBAM***: added many of passive solutions suitable to hot dry climate like building orientation, vertical and horizontal sun-screen, use of HVAC system, water cooler, use of fans, indoor solutions like use of curtains, courtyard system, wind tower, building form, windows design.

***3. Energy and atmosphere:***

The Table 9: Concluded that the Energy is as follows:

**Table 7.1. Energy and atmosphere**

| The Issues of each categories 2-Energy and Atmosphere | BREEAM | LEED V4 | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| Fundamental Commissioning of the Building Energy Systems | ○ | ● | ○ | ○ | ○ | ○ |
| Minimum Energy Performance | ○ | ● | ○ | ○ | ○ | ○ |
| Fundamental Refrigerant Management | ○ | ● | ○ | ○ | ○ | ○ |
| Optimize Energy Performance | ○ | ● | ● | ○ | ○ | ○ |
| On-Site Renewable Energy | ○ | ● | ● | ● | ○ | ○ |
| Enhanced Commissioning | ○ | ● | ○ | ○ | ○ | ○ |
| Measurement & Verification | ○ | ● | ● | ○ | ○ | ○ |
| Green Power | ○ | ● | ● | ○ | ○ | ○ |
| HVAC Controls | ○ | ○ | ● | ○ | ○ | ○ |
| HVAC System Simulations | ○ | ○ | ● | ○ | ○ | ○ |
| Building Envelope | ○ | ○ | ● | ○ | ○ | ○ |
| A/C Pumping | ○ | ○ | ● | ○ | ○ | ○ |
| Modelling Information | ○ | ○ | ● | ○ | ○ | ○ |
| Community Energy Strategy | ○ | ○ | ○ | ● | ○ | ○ |
| Building Energy Guidelines | ○ | ○ | ○ | ● | ○ | ○ |
| Energy Monitoring and Reporting | ● | ○ | ○ | ● | ○ | ○ |
| Community Strategies for Passive Cooling | ○ | ○ | ○ | ● | ○ | ○ |
| Efficient Infrastructure: District Cooling | ○ | ○ | ○ | ● | ○ | ○ |
| Efficient Infrastructure: Smart Grid Technology | ○ | ○ | ○ | ● | ○ | ○ |
| Renewable Energy: Offsite | ○ | ○ | ○ | ● | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Energy Efficient Buildings | ○ | ○ | ○ | ● | ○ | ○ |
| Energy Demand Performance | ○ | ○ | ○ | ○ | ● | ○ |
| Energy Delivery Performance | ○ | ○ | ○ | ○ | ● | ○ |
| Fossil Fuel Conservation | ○ | ○ | ○ | ○ | ● | ○ |
| CO2 Emissions | ○ | ○ | ○ | ○ | ● | ○ |
| NOX, SOX, & Particulate Matter | ○ | ○ | ○ | ○ | ● | ○ |
| Reduce energy use and carbon emissions | ● | ○ | ○ | ○ | ○ | ○ |
| External lighting | ● | ○ | ○ | ○ | ○ | ○ |
| Low carbon Design | ● | ○ | ○ | ○ | ○ | ○ |
| Energy efficient cold storage | ● | ○ | ○ | ○ | ○ | ○ |
| Energy efficient transportation systems | ● | ○ | ○ | ○ | ○ | ○ |
| Energy efficient laboratory systems | ● | ○ | ○ | ○ | ○ | ○ |
| Energy efficient equipment | ● | ○ | ○ | ○ | ○ | ○ |
| Drying space | ○ | ○ | ○ | ○ | ○ | ○ |
| Solar panel system | ○ | ○ | ○ | ○ | ○ | ● |
| Metering System | ○ | ○ | ○ | ○ | ○ | ● |
| Smart solution | ○ | ○ | ○ | ○ | ○ | ● |

Source: Designed by the researcher.

***The similarities in the main issues of Energy category are***: Optimize Energy Performance, On-Site Renewable Energy, and Measurement & Verification, energy monitoring and reporting, green power.

Green Power.

***The differences in the main issues of Energy category are***:

I. **BREEAM**; Added more additional issues in Reduce energy use and carbon emissions, External lighting.

II. Low carbon Design, Energy efficient cold storage, Energy efficient transportation systems, Energy efficient laboratory systems, Energy efficient equipment and Drying space.

III. **LEED**: added more additional issues in Energy and Atmosphere Category which are: Commissioning of the Building Energy Systems, Minimum Energy Performance, Fundamental Refrigerant Management, Optimize Energy Performance, energy metering, enhance commissioning, renewable energy, green power, refrigerant management.

IV. **Australia**: added new additional issues which are essential on contemporary design on shopping malls, educational and office buildings: HVAC system, HVAC System Simulations, Building Envelope, A/C Pumping, Modelling Information.

V. **ESTIDAMA**: added new additional issues in Energy and Atmosphere Category which are: Community Energy Strategy, Building Energy Guidelines, Energy Monitoring and Reporting, Community Strategies for Passive Cooling, Efficient Infrastructure: District Cooling, Efficient Infrastructure: Smart Grid Technology, Renewable Energy: Offsite, Energy Efficient Buildings.

VI. **QSAS**: added additional issues in Energy which are: Energy Demand Performance, Energy Delivery Performance, Fossil Fuel Conservation, Fossil Fuel Conservation, CO2 Emissions, NOX, SOX, & Particulate Matter.

VII. **SEBAM**: Added solar panel applied in suburb areas and residential buildings, energy metering system, smart solutions in energy efficiency .

***4. Water efficiency:***

(Table 10): Concluded the water efficiency as follows:

**Table 7.2. The water efficiency**

| The Issues of each categories 4-Water | BREEAM | LEED V4. System | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| Water Efficient Landscaping, Reduce by 50% | ○ | ● | ○ | ● | ○ | ○ |
| Water Efficient Landscaping, No Potable Use or No Irrigation | ○ | ● | ○ | ● | ○ | ○ |
| Innovative Wastewater Technologies | ○ | ● | ○ | ○ | ○ | ○ |
| Water Use Reduction, 20% Reduction | ○ | ● | ○ | ● | ○ | ○ |
| Water Use Reduction, 30% Reduction | ○ | ● | ○ | ○ | ○ | ○ |
| Solar collectors | ○ | ○ | ● | ○ | ○ | ○ |
| Hot water rating load | ○ | ○ | ● | ○ | ○ | ○ |
| Measurements | ○ | ○ | ● | ○ | ○ | ○ |
| water reuse | ○ | ○ | ● | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Community Water Strategy | ○ | ○ | ○ | ● | ○ | ○ |
| Building Water Guidelines | ○ | ○ | ○ | ● | ○ | ○ |
| Water Monitoring & Leak Detection | ○ | ● | ○ | ● | ○ | ○ |
| Community Water Use Reduction | ○ | ● | ○ | ● | ○ | ○ |
| Community Water Use Reduction: Heat Rejection | ○ | ● | ○ | ● | ○ | ○ |
| Community Water Use Reduction: Water Features | ○ | ○ | ○ | ● | ○ | ○ |
| Storm water Management | ○ | ○ | ○ | ● | ○ | ○ |
| Water Efficient Buildings & Plots | ○ | ○ | ○ | ● | ○ | ○ |
| Water Consumption | ● | ○ | ○ | ○ | ● | ○ |
| Water monitoring | ● | ○ | ○ | ○ | ○ | ○ |
| Water leak detection | ● | ○ | ○ | ○ | ○ | ○ |
| Water efficient equipment | ● | ○ | ○ | ○ | ○ | ○ |
| Water metering system | ○ | ○ | ○ | ○ | ○ | ● |
| Grey Water recycling | ○ | ○ | ○ | ○ | ○ | ● |
| Water efficiency | ○ | ○ | ○ | ○ | ○ | ● |

Source: Designed by the researcher

***The similarities in the main issues of water category are***: Water Efficient Landscaping, Water Use Reduction and water consumption.

***The differences in the main issues of water category are***:

I. **BREEAM** added more additional issues for water which are water consumption, water monitoring, water detection and water efficient equipment.

II. **LEED**: added more additional issues for water category which are: Innovative Wastewater Technologies., outdoor water reduction, indoor water reduction, water metering, and cooling tower.

III. **Australia**: added new additional issues which are: Solar collectors, Hot water rating load, Measurements, water reuse.

IV. **ESTIDAMA**: added new additional issues in water which are: Community Water Strategy, Building Water Guidelines, Water Monitoring & Leak Detection, and Community Water Use Reduction Community Water Use Reduction: Water Features, Storm water Management, Water Efficient Buildings & Plots.

V. **QSAS**: added additional issue in water, which is Water Consumption.

VI. **SEBAM** added water metering system, grey water recycling and water efficiency

***5. Materials***

Table 7.3: Concluded that the materials are as follows:

**Table 7.3. The materials**

| The Issues of each categories 2-materials | BREEAM | LEED V4. | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| Building Reuse, Maintain 75% of Existing Walls, Floors & Roof | ○ | ● | ○ | ○ | ○ | ○ |
| Building Reuse, Maintain 95% of Existing Walls, Floors & Roof | ○ | ● | ○ | ○ | ○ | ○ |
| Building Reuse, Maintain 50% of Interior Non-Structural Elements Construction Waste Management, Divert 50% from Disposal | ○ | ● | ○ | ○ | ○ | ○ |
| Construction Waste Management, Divert 75% from Disposal | ○ | ● | ● | ○ | ○ | ○ |
| Materials Reuse, 5% | ○ | ● | ● | ○ | ○ | ○ |
| Materials Reuse,10% | ○ | ● | ○ | ○ | ○ | ○ |
| Recycled Content, 10% (post-consumer + ½ pre-consumer) | ○ | ● | ○ | ● | ○ | ○ |
| Recycled Content, 20% (post-consumer + ½ pre-consumer) | ○ | ● | ● | ● | ● | ○ |
| Regional Materials, 20% Extracted, Processed & Manufactured Regionally | ○ | ● | ○ | ● | ● | ○ |
| Rapidly Renewable Materials | ○ | ● | ○ | ○ | ○ | ○ |
| Certified Wood | ○ | ● | ○ | ○ | ○ | ○ |
| Basic Construction Waste Management | ○ | ○ | ○ | ○ | ○ | ○ |
| Reused or Certified Timber | ○ | ○ | ○ | ○ | ○ | ○ |
| Improved Construction Waste Management | ○ | ○ | ○ | ○ | ○ | ○ |
| Improved Operational Waste Management | ○ | ○ | ○ | ○ | ○ | ○ |
| Organic Waste Management | ○ | ○ | ○ | ○ | ○ | ○ |
| Hazardous Waste Management | ○ | ● | ○ | ○ | ○ | ○ |
| Life Cycle Assessment (LCA) | ● | ○ | ○ | ○ | ○ | ○ |
| Eco Content | ○ | ○ | ○ | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Durability | ○ | ● | ○ | ○ | ○ | ○ |
| Environmental management system | ○ | ○ | ○ | ○ | ○ | ○ |
| Product stewardship | ○ | ● | ○ | ○ | ○ | ○ |
| Storage for recycling materials | ○ | ○ | ○ | ○ | ○ | ○ |
| Hard landscaping and boundary protection | ● | ○ | ○ | ○ | ○ | ○ |
| Responsible sourcing of materials | ● | ○ | ○ | ○ | ○ | ○ |
| Insulation | ● | ○ | ○ | ○ | ○ | ○ |
| Design for durability and resilience | ● | ○ | ○ | ○ | ○ | ○ |
| Material efficiency | ● | ○ | ○ | ○ | ○ | ○ |
| Local Building materials | ○ | ○ | ○ | ○ | ○ | ● |
| Material used in buildings roof, walls and floors | ○ | ○ | ○ | ○ | ○ | ● |
| Life cycle analysis | ○ | ○ | ○ | ○ | ○ | ● |
| Regional building materials | ○ | ○ | ○ | ○ | ○ | ● |

Source: Designed by the researcher

**The similarities in the main issues of material category are**:

Construction Waste Management, Materials Reuse, Recycled Content, Regional Materials, Certified Wood, and **the differences in the main issues of material categories are**:

I. **BREEAM** added more additional issues for material categories which are Hard landscaping and boundary protection, Responsible sourcing of materials, Responsible sourcing of materials, Design for durability and resilience and Material efficiency.

II. **LEED** v4: added more additional issues for material categories which are: Building Reuse, maintain 75% of Existing Walls, Floors & Roof, and Building Reuse, Maintain 95% of Existing Walls, Floors & Roof, Rapidly Renewable Materials, storage recycling, LCA, waste management, and raw materials. Construction waste management planning, building life cycle analysis, environmental products, use of raw materials, Australia rating system added.

III. **Australia**: added more additional issues for material categories, which are: Eco content, durability, environmental management system, product stewardship (reuse- recycle-repressing) and Modular design.

IV. **ESTIDAMA**: They add new additional issues in material, which are: Basic Construction Waste Management, Reused or Certified Timber, Improved Operational Waste Management, Organic Waste Management, Hazardous Waste Management.

V. **QSAS**: added material recycling and material reuse.

**VI.** **SEBAM**: Added local building materials, material used in building roof, walls and ceiling, regional building materials and life cycle analysis.

## 7.6. Conclusion of the common categories

The common categories between the four systems are sustainable site, indoor environmental quality, material, water and energy and Innovation in design.

The main categories of LEED V4 are: Site location (16 points), Sustainable site (10 points), indoor environmental quality (16 points), the energy (33points), the water (11 points), the material (13 points) and the innovation. The assessment method is based on each category has identified weighing (6 points), regional priority (4 points). Then the total numbers of points are 110 points.

The building certified as: Certified: 20-46, Silver.50-59 points, Gold: 60-79 points, Platinum: 80-and above.

Positive point of LEED's system that it has been a system developed since 2000 through 2013 and has been reviewed four times, where we now find LEED 2009, LEED V3 and LEED V4, and from time to time is announced in USGBC.org website of United state Green Building Council for members who are interested to share their experience to develop LEED process it takes about six months review 1 and review 2 and review3 they listen to experts, professionals and users views towards improvement of the negative notes into possible positive issues.

As well ; it contains sub issues that help in managing certain local and global problems, for example the local problems i.e. : storm water design in Sustainable site category; and examples for global problems that have an effect on the local environment heat island effect, smoke control and optimize energy performance.

### 7.6.1. The main categories of global assessment methods

Table 4.2 concludes the main categories of the global assessment methods and the common points, i.e., sustainable site, indoor environmental quality, energy, water, and materials.

Legend for Table 7.4:

- ● signifies an applicable solution to the building
- ○ signifies a non-applicable solution to the building

Correspondingly, the architect or professional associate decides if the solution is applicable or not applicable to the building.

**Table 7.4. The main categories of global building assessment methods**

| The main Categories | BREEAM | LEED V4 | Australia green star rating system | ESTIDAMA | GSAS | SEBAM |
|---|---|---|---|---|---|---|
| Sustainable Site | ○ | ● | ● | ○ | ● | ● |
| Indoor environmental quality | ○ | ● | ● | ○ | ● | ● |
| Energy and atmosphere | ● | ● | ● | ● | ● | ● |
| Water Efficiency | ● | ● | ● | ● | ● | ● |
| Material and resources | ● | ● | ● | ● | ● | ● |
| Innovation in design | ● | ● | ● | ● | ● | ○ |
| Regional priority | ○ | ● | ○ | ○ | ○ | ○ |
| Management and operation | ○ | ○ | ● | ○ | ● | ○ |
| Transportation | ● | ○ | ● | ○ | ○ | ○ |
| Land Ecology | ● | ○ | ● | ○ | ○ | ○ |
| Urban community | ○ | ○ | ○ | ● | ● | ○ |
| Culture and economic value | ○ | ○ | ○ | ○ | ● | ○ |
| Integrated development process | ○ | ○ | ○ | ● | ○ | ○ |
| Natural system | ○ | ○ | ○ | ● | ○ | ○ |
| Pollution | ● | ○ | ○ | ○ | ○ | ○ |
| Health | ● | ○ | ○ | ○ | ○ | ○ |
| Waste | ● | ○ | ○ | ○ | ○ | ○ |
| Building Form | ● | ○ | ○ | ○ | ○ | ● |
| Outdoor environment | ● | ○ | ○ | ○ | ○ | ● |
| Environmental Design Process | ● | ○ | ○ | ○ | ○ | ● |

Source: Khogali H. 2019

From the table 7.5, which presents a comparison between the five global systems the researcher highlights the following points:

I. The five global systems demonstrate similarities for the following factors: Sustainable site, indoor environmental quality, building materials, energy and water.

II. Additional diverse categories were added by these countries to solve specific local - environmental, social and economic problems.

III. Lastly, from the researcher's perspectives, within the context of Khartoum residential buildings, categories like; outdoor environment, land ecology, health and integrated development process could be significantly useful.

### 7.6.2. The Additional Categories Was Added by the Global Assessment Methods

**BREEAM** added new more categories which are Hard landscaping and boundary protection, Responsible sourcing of materials, Responsible sourcing of materials, Design for durability and resilience and Material efficiency.

**LEED**: added regional priority, Innovation and Site location.

**Australia green star** system provides new additional categories which are:

**Management** Credits addressed the adoption of sustainable development principles from project conception through design, construction, commissioning, tuning and operation:

**Transportation** Credits reward the reduction of demand for individual cars by both discouraging car commuting and encouraging use of alternative transportation.

**Land ecology**: Credits address a project's impact on its immediate ecosystem, by discouraging degradation and encouraging restoration of flora and fauna.

**ESTIDAMA**: Urban community, integrated development process, Natural System.

**Urban Community consist of**: Plan 2030, Urban Systems Assessment, Provision of Amenities and Facilities, Outdoor Thermal Comfort Strategy, Minimum Pearl Rated Buildings Within Communities, Transit Supportive Practices, Neighborhood Connectivity, Open Space Network, Accessible Community Facilities, Housing Diversity, Community Walk ability, Active Urban Environments, Travel Plan, Improved Outdoor Thermal Comfort, Regionally Responsive Planning, Pearl Rated Buildings Within Communities, Safe and Secure Community.

**Integrated development process consists of**:

Integrated Development Strategy, Sustainable Building Guidelines, Community- Dedicated Infrastructure Basic Commissioning, Life Cycle Costing, Guest Worker Accommodation, Construction Environmental Management, Sustainability Awareness.

**Natural System consists of**:

Natural Systems Design and Management Strategy Reuse of Land, Remediation of Contaminated Land, Ecological Enhancement, Habitat Creation and Restoration, Food Systems.

QSAS: Urban Community, Culture and economic value.

**Urban Community consists of**:

Proximity to Infrastructure, Transportation Load, Load on Local Traffic Conditions, Solid Waste Load, Pedestrian Pathways and Wastewater Load

**Culture and economic value**:

The building's cultural and economic values shall be maintained or enhanced

i. Encouraging designs to align with cultural identity and traditions.
ii. Designing for seamless integration into the existing cultural fabric.
iii. Planning for the use of local materials and workforce.
iv. Encouraging sustainable business partnerships within the community.
v. Constructing a diverse mix of housing typologies.
vi. These new categories have been added to satisfy the need for connecting the design with local culture, economic and local community and local environment.

**SEBAM** Added outdoor environment category, Building form Category and Environmental design process category.

### 7.6.3. Availability

Availability needs to be usable on all of its project and building types. All the Global systems in this comparison are applicable in many of buildings type. See Table 7.5 which concludes the availability as follows.

**Table 7.5. The availability of each system**

| | BREEAM | LEED V.4 | GBCA | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| Land use | ● | ○ | ○ | ○ | ○ | ○ |
| Infrastructure | ● | ○ | ○ | ○ | ○ | ○ |
| The System | ● | ○ | ○ | ○ | ○ | ○ |
| New construction | ● | ● | ● | ○ | ● | ● |
| Existing building | ● | ● | ○ | ○ | ● | ● |
| Shell core | ● | ● | ● | ● | ● | ● |
| Commercial | ● | ● | ● | ● | ● | ● |
| Retail | ● | ○ | ● | ● | ● | ● |
| Schools | ● | ○ | ● | ● | ● | ● |
| Homes | ● | ○ | ● | ● | ● | ● |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neighborhood Development | ● | ○ | ● | ● | ● | ● |
| Healthcare | ● | ○ | ● | ● | ● | ● |
| Education | ○ | ○ | ● | ● | ● | ● |
| Office | ○ | ○ | ● | ● | ● | ● |
| Industrial | ○ | ○ | ● | ● | ● | ● |
| Mix use | ○ | ○ | ○ | ● | ● | ● |
| Residential | ● | ● | ● | ● | ● | ● |
| Mosque | ○ | ○ | ○ | ○ | ● | ● |
| Hotel | ○ | ○ | ○ | ○ | ● | ● |
| Operation | ○ | ○ | ○ | ○ | ● | ● |

Source: Designed by the researcher.

**BREEAM** is applicable to land use, infrastructure, the system, commercial, all types of buildings.

**LEED**: Applicable to new construction, existing buildings, commercial buildings, schools, neighborhood, and healthcare. Warehouses, hospitals, data centers, mid-rise residential.

**GBCA**: Applicable to new construction, healthcare and education.

**ESTIDAMA**: new construction, schools, mix use, residential and retails.

**QSAS**: new construction, commercial buildings, homes, schools, neighborhood, residential, mosque, hotel, operation and sport.

**SEBAM**: Applicable in Residential buildings and Neighborhood.

### 7.6.4. Applicability

Since when is this system applicable?

Table 7.6 discusses the applicability of each system as follows:

**Table 7.6. The applicability of each system**

| Applicability | BREEAM | LEED V4. | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| | ● | ● | ● | ● | ● | ● |

Source designed by the researcher.

**BREEAM** is applicable since 1990 started in latest 1990.

**LEED**: applicable since the year 2000 and they stated with LEED V1 on 2006, LEED V.2 in 2007, LEED V3 latest 2010 and LEED V4 latest 2012.

**Australia**: Applicable since 2008

**ESTIDAMA**: Applicable since 2009

**QSAS**: Applicable since 2009

**SEBAM**: Applicable in 2019

### 7.6.5. Development

The study of the method of development will be carried out through Government, Private, Industry, NGO and Experts Opinion. Table 7.8 shows the development of each system as follows:

**Table 7.7. The development of each systems**

| Development | BREEAM | LEED V4. | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| Government | ● | ● | ● | ● | ● | ● |
| Private | ● | ● | ● | ● | ● | ● |
| Industry | ● | ● | ● | ● | ● | ● |
| NGOs | ● | ● | ● | ● | ● | ● |
| Expert opinion | ● | ● | ● | ● | ● | ● |

Source: Designed by the researcher

**BREEAM** Development by bre Academy.

**LEED**: developed by the U.S. Green Building Council member committees. The U.S. Green Building Council is a non-profit organization.

**GBCA**: developed by GBCA.

**ESTIDAM**: developed by Abu Dhabi Urban planning council.

**QSAS**: developed by Gulf Organization for research and development. subsidiary of QATARI DIAR Real Estate Investment Company) - is a fully governmental Organization located at the Qatar Science and Technology Park (QSTP); which objective is to promote healthy, energy & resources efficiency, and environmentally responsible building practices in Qatar and the entire Gulf region.

**SEBAM**: Developed by SGBC .

#### 7.6.6. Durability

The life cycle analysis is provided or not?

Table 7.9 shows the durability of each system through LCA.

**Table 7.8. The durability of the system**

| Durability | BREEAM | LEED V4. System | Australia green star rating system | ESTIDAMA | QSAS | SEBAM |
|---|---|---|---|---|---|---|
| LCA | Applicable | Applicable | N/A | N/A | N/A | Applicable |

Source: Designed by the researcher

Roaf, 2001 defined the life cycle analysis as:

"*Life cycle analysis: It is used as a way of assessing the total impact of any building and shows the importance of the building's lifespan. The longer a house can last, the lower the impact of the energy and pollution resulting from the manufacture of its materials will be. A simple way to think about this is to consider the initial embodied energy of an entire building and divide this figure over its lifetime, making an allowance for maintenance*".

We should provide the LCA for each material, products and manufacturer's warranty.

Eco building materials are preferred, recycling materials, re-use, re-processing.

I. **BREEAM** is applying LCA.

II. **LEED**: LCA is applied to LEED V4, in manufacture of building materials and equipment, recycling/ reuse process.

III. **Australia**: LCA not applicable.

IV. **ESTIDAMA**: LCA not applicable.

V. **QSAS**: not applied LCA.

VI. **SEBAM** applied LCA.

## 7.7. PART II: in discussion and analysis

#### 7.7.1. Additional Categories from Researcher Point of View for Hot Dry Climate Added by SEBAM.

This analysis study is the based study for PhD research to emerge by new categories suitable for hot dry climate.

Will be discussed in the following:

### 7.7.2. The Location and the Environmental Issues.

The second part of the study introduces additional categories suitable for hot- dry climate; which are not presented by the five global systems. The location of the case study carried out in Greater Khartoum city, which consists of the three towns, the capital Khartoum, Khartoum North city and Omdurman city. It is located between latitude 15° 36' north and longitude 32° 3 east, with an altitude of 380 meters above sea level.

The climate described as hot dry climate, the temperature in summer ranges between 40°C to 45°C, in winter it drops to 14°C to 25°C, rainfall ranges between 100mm to 150- mm. Relative humidity is 40% to 60% of Greater Khartoum area is experiencing floods, desertification and rare earthquakes. Wide variety of natural vegetation's covers the surrounding lands of the River Nile.

### 7.7.3. Health Safety and Emission

None of the four Global Rating Systems provides health safety and emission as important Category.

Health safety and emission are the most important categories to be added and therefore, healthy houses, minimized emission of $CO_2$, and use of nontoxic building materials, should be provided to ensure secure building safety procedures. Focusing on the direct application of techniques and strategies that advance the concept of sustainable design, as defined above. All these topics deal with or affect the health, safety and welfare of the public and the communities at large.

***Health***

Roof, S., Fuentes M. and Thomas (2001) S. Op cit, discussed human health, asbestosis, asthma, and allergic skin reactions to asbestos exposure, nontoxic building material and provision of impervious dust screen.

***Safety procedure***

Pank, 2002 discussed safety procedures in building sector like: Enhancement of earthquakes resistance and adoption of Fire Safety Engineering. Fire safety engineering is a relatively new discipline, which has developed in recent years especially, to meet fire control solutions in buildings that fall outside of the current codes such as large and complex buildings demonstrate that the proposed fire solutions meet or outperform the requirements of the intent of the regulations.

**Building is Permanent Fire Brigade.**

Although it is not mandatory, additional security measures have been adopted against fire accidents and have developed firefighting by stationing of firefighting crews in the UK, other European countries, such as Fraermanepntly stationed, within the building.

***Phased Evacuation.***

Protected escape routes in tall buildings must be managed effectively. To avoid excessively wide escape stairs, needed to evacuate several thousand people at the same time, phased evacuation is common. In this regard, the services within the building are shut down on the floor, where an alarm is raised together with one or two floors above and one floor below, and these floors are evacuated first. Fire protection of the building structure is related to evacuation times by a risk assessment approach - the longer the time for total evacuation of a building, the greater the provision for fire protection.

***Fire Fighting Shafts and Lifts***

For tall buildings, protected access within the building for firefighting can be provided by the design of firefighting shafts. Firefighting lifts are currently used for heights greater than 18 m.

***Smoke Control***

Staircase pressurization and smoke control systems are provided in fire rated airshafts. Smoke dampers activated by the Fire Alarm System are used in air conditioning and ventilation ducts.

***Sprinkler Protection and Gas Flooding Systems***

Sprinkler protection is provided throughout the building, as an automatic means of firefighting and controlling a fire during its initial growth. Gas flooding systems may be considered in specialist areas, such as computer data rooms, where sprinkler systems are undesirable.

***Emissions***

Roaf, 2001 as well as, discussed gaseous emissions, in eco house we can avoid emissions by using exhaust fans, and clean energy in order to minimize CO2 emissions by proper ventilations. Carbon dioxide CO2, carbon monoxide CO in breathing and combustion inside the house, they are sources of air pollution, and Chlorofluorocarbons (CFCS).

In insulates, aerosols, refrigerants and fire extinguishers are responsible for destroying the ozone layer above the Earth that shields the planet from incoming radiation. Roaf, 2001 stated that we should avoid toxic building materials such as PVC and use eco building materials in paints and plaster.

### 7.7.4. The Outdoor Environment

BREEAM consider the ecological site, QSAS added the outdoor environment as new category in their FINAL DRAFT QSAS QUIDE (development, 2012). ESTIDAMA provides outdoor thermal comfort strategy inside liveable community category.

**For Greater Khartoum** it's very important to improve the outdoor thermal environment by controlling the design by providing shades to the building in North direction, South direction and enhance landscaping on sides with plants and trees that can provides more shades; fences protect the site from dust swimming pools and fountains modify the dry climate to humid climate. Khartoum residents take concern very much towards the outdoor environment where the climate is hot and dry. Khartoum residents spend part of their time, particularly nights times, in the gardens which are also enjoyed during holidays and celebrations.

***Ecological***

Lmdc, 2005 discussed thermal comfort in outdoor environment and said that: bringing people outdoors reduces demands for in indoor spaces and provides increased opportunities for contact with the natural world. Reduced demand on indoor spaces reduces indoor light and air conditioning energy requirements.

In order to improve their health, urban dwellers are required to increase their exercise activities and inhale more fresh air during daylight since they spend a large portion of their time staying indoors. As their contact with natural environment increases, their life- stress will be reduced, and more opportunities for rest and relaxation will be available to them. Creating opportunities for people to go outdoors and be in connection with nature will also arouse their awareness of these atmospheres and their role in sustaining them.

***Economic***

Increasing and extending the amount of time spent in comfortable outdoor spaces, provides increased and extended opportunities for outdoor retailing, dining has direct economic benefits in both, increased productivity and reduced medical costs.

***Social***

Outdoor spaces could enhance the level of social interaction that occurs in a neighborhood. A comfortable outdoor space is likely to be utilized more frequently where increased presence of people outside boosts the security of the premises and contribute to deter crime.

***Landscape and Buildings Work Together***

(The Ministry of Environment, 2006) stated that perm culture adoption and application of organic techniques, rather than other techniques which could go against nature. The goal of permaculture is to create natural life supporting systems even in the smallest most urban areas. Healthier, more integrated environment results, when we combine the inherent qualities of plants and animals with the natural characteristics of landscapes and structure. Shafiq, 2010 stated in his paper "Sustainability of Traditional and contemporary architecture" that uses of plants and trees reduce the cooling bill by 15-35% beside application of windows shades and sun screen from plants serve 10% of cooling system costs.

***The Basic Understanding of Landscape Design and Its Elements***

Awad, 2007 discussed in a paper, "The elements of landscape or landscape architecture design" and said that these elements are divided into two main parts: plants and trees, space of air mass, buildings, civil and mechanical construction, elements of landscape, ecological features.

***Conclusion of Outdoor Environmental Control:***

- In Sudan it is very important to improve the outdoor environment and provide thermal control
- provide shades and terraces and balconies
- provide swimming pools
- provide fountains
- maximize the outdoor environment in view of its physiological, ecological and economical and social aspect as specified, in order to make the air more humid and comfortable.

### 7.7.5. The Building Form

***None of the four Global systems Added Building Form as important Category.***

We have different buildings forms, cubic form, linear form, L-form, U- form, circular forms. There are many factors that compel and urge us to prefer a particular form over the others:

- Building location, whether the building is located on a top of a mountain or on flat land, cold areas or wet or hot dry climate each location requires specific form.
- The climate: whether the building is located in hot climate zone or cold climate. In cold areas it is better to use cubic form while in hot climate its preferred to use L-form or U-form or leaner form, as they provide good ventilation.
- The sun position: it is very important to study the sun movement in a specific location in order to determine the building form and shape. The building form secures more shades and minimizes the solar radiation.
- The Heat exchanger: The greater the volume of the building the more exposed surface area it has to lose or gain heat, Roaf, S., Fuentes M. and Thomas, S. ( 2001 ) discussed the building form in several cases such as: building as an analogy, the Ice House, the tea cosy cottage, the green house , the nomadic tents and the igloo. Figure 1 shows that different plan forms can have more or less wall area for the same plan area.
- The surface area: volume ratio is very important in conserving heat transfer into and out of a building. To conserve heat or cold, the building must be designed with a compact form to reduce the efficiency of the building as a heat exchanger. Buildings can have very different perimeters: area ratios depending on their plan form. See figure. 3 shows Buildings forms.
- The building form also changes according to building function; we have found that linear form is suitable to schools, office buildings. The Cubic and U form is suitable to hospitals and circular form is suitable to exhibitions.
- Building information modelling (BIM) and energy simulation software are used to understand and predict the effect of building form on energy use for various design concepts in the early stages of the design.
- The orientation of the building should be perpendicular to the direction of the wind. It is worth to note that some experiments proved that greater velocities of the air could be obtained inside a building, if the orientation is kept at 45 degrees with the direction of the wind and offer more wind shaded area (Hassan, 2001) discussed the relation between building orientation and the wind direction and said that his good orientation of the building makes the house healthier, and by studying of sun rises and sun sets locations we shall be more knowledgeable of the direction of the shades made for the gardens and terraces.

- If we consider all the above-mentioned criteria, we can apply the sustainability and durability of the building.
- The building form is developing through the history and people are always choosing the form suitable to their local environment and local climate. The nomadic tent shows a good example of an adaptable building form. Figure. 4 is showing the buildings form and their orientation and surface volume Ratio. Figure 4 shows the relation between building form and the surface volume ratio (SVR) and building orientation

### 7.7.6. The Holism and Environmental Design Process

***Holism***

The term holism has been used to describe the view that a whole system must be considered, rather than simply its individual components. The Vales have addressed this point in their book Green Architecture, suggesting that a building should attempt to address all the principles of green design in a holistic manner (Vale and Vale, 1991). Holism emphasizes the relationship between the parts and the whole. Another dimension of holism comes from an engineering perspective and relates to the synergy between systems, which is a critical part of the physicality of a house. Holism can mean the way in which systems are integrated within the home – for example, the way, in which the solar system is integrated with the roof or, the water recycling system is integrated with the irrigation system. In summary, the outcome of holism can create and lead to greater improvements in environmental performance. (Hide, 2008)

Identify of the whole design process from the design initial stages and the design pass through three phases:

***Pre-Building Phase***:

Pre building phase is the design phase, primary, developed and final design. Adoption of sustainable eco-building categories to be as main goals.

***Building phase***:

Building phase is in construction and operation system, in this level, dealing with contractors and suppliers apply appropriate technologies in mechanical system and construction waste disposal and control of noise in site.

***Post Building Phase:***

After building construction has been completed come the users' role who should observe regular maintenance of the building, in order to ensure building long life and durability and improve of the Rating System through regular reviews by stakeholders and frequent survey by the users of the system in order to maintain and manage the difficulties.

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