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Life Cycle Assessment for Building Materials Constituents using Gabi vs OpenLCA

Ahmed Tharwat Maaly[1], Ola Diaa El Monayeri[1,*], Mohamed Ashraf ElSayad[1]

[1] Department of Construction and Building Engineering, Faculty of Engineering, Arab Academy for Science, Technology and Maritime Transportation, Cairo, Egypt

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ABSTRACT

Cement and paint are two essential construction materials whose manufacturing processes contribute to air pollution and global warming leading to climatic changes. In this research, a life cycle assessment was done using GaBi and OpenLCA simulating tool to study chemical constituents' percentages impact for cement and paint on climate change; acidification; eutrophication, and human toxicity. Results showed that calcium oxide is the main raw material causing pollution in cement manufacturing. From cement charts, the lowest impacts were from the mixture that contained 71.6% calcium oxide. But, from the paint charts, the weakest impacts were from the mixture (WN- RU). These results showed that: reducing the values of the impact categories could be achieved by reducing the participation rates of raw materials with a significant environmental impact in the mixture or replacing the mix of high ecological impact with another mixture, regarding the same quality of the building material.

1. Introduction

Lately, the world has been suffering from increasing greenhouse gases, which are: carbon dioxide (fossil fuels and deforestation were sources of CO2), methane (Agricultural activities, waste management, and energy use were sources of CH_4), nitrogen oxides (Agricultural activities, such as fertilizer use were sources of NOx), and Chlorofluorocarbons (CFCs) which are divided into Hydrofluorocarbons (HFCs) & Perfluorocarbons (PFCs) whereas Industrial processes and refrigeration were considered sources of CFCs [1].

Greenhouse gases were produced when manufacturing building materials according to Ali *et al.*, [2] and because the use of building materials increased significantly, more research is needed to reduce these environmental effects by either improving the production steps of building materials or identifying alternative building materials that have less environmental effects than building materials with higher environmental

* *Corresponding author.*
E-mail address: omonayeri@aast.edu

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effects. Ceramics, cement, paint, steel, glass, burnt clay bricks, and wood are a variety of the most often utilized building supplies on the Egyptian domestic market that have different amounts of different environmental impacts.

Nearly 40% of CO_2 emissions result from energy use worldwide and more than 35% of global GHG emissions are produced by the construction industry [3]. The cement industry is considered among Egypt's biggest industries. The first cement factory was built in 1911 in an area near Helwan called Al-Masara. The Tora Cement Company is the first Egyptian cement company established in 1927. The number of cement companies in Egypt is around 18, and the total productivity is around 70 million tons. About 83% of consumption is made locally, and 17% is exported [4].

The resin type, technology, and end-user industry are the three segments that makeup Egypt's paint and coatings market. Market segmentation by resin type includes Acrylic, Alkyd, Polyurethane, Epoxy, and Polyester, in addition to others; market segmentation by technology includes Water-borne, Solvent-borne, and other technologies; and market segmentation by end-user industry includes Protective, Automotive, Wood, Architectural, and Other End-user Industries.

This study aims to deduct consequences of building materials throughout the life cycle by conducting an environmental assessment of those effects through different operating systems the impact categories under study resulting from this assessment are: acidification - climate change - global warming - eutrophication - human toxicity.

1.1 Background

To convey the possible harm that a chemical unit released into the environment might cause, the quantitative toxic equivalency potential (TEP) known as "human toxicity" was first established [5]. Sustainability, according to Kotob *et al.*, [8], is development that satisfies the demands of the current generation. putting future generations' capacity to meet their own needs at risk. As stated by Yildiz *et al.*, [9], A method for evaluating a product's environmental impact at every stage of its life cycle is called a life cycle assessment, including the procurement of raw materials, manipulating, manufacture, distribution, use, repair, maintenance, and end of life or recycling.

The developing of nanotechnologies are anticipated to have a significant impact on the creation of novel building materials. On the other hand, generating LCA of these technologies figured out the influence on the safety, human health, and environment. However, new composition increased paint longevity over time span that minimizes paint consumption during a building's life cycle [6]. Since construction materials are the first and most significant component of a building, according to Mittal *et al.*, [10], sustainable design also includes using eco-friendly building materials in addition to planting trees and utilizing locally produced materials. The materials that go into a construction determine how long it will last. Choosing eco-friendly materials is therefore a quick step toward creating a constructed environment that is both sustainable and environmentally beneficial [7].

1.2 Problem Definition

Building materials may have a number of harmful consequences on the environment, including acidification, climate change, global warming, eutrophication, and human toxicity. Environmental influences represent a great danger to the environment, so reducing these effects is an aspired goal that must be achieved to preserve the environment, especially since these effects result from building materials present in all construction elements around us. Products made of paint also have a high VOC content. When exposed to sunlight, volatile organic compounds, or VOCs, combine with oxygen to generate an ozone layer. As part of the greenhouse effect, this ozone is assumed to play a role in air pollution and global warming. According to Ruzena *et al.*, [11], VOCs can affect the liver, kidneys, and the respiratory tract.

1.3 Scope of Work and Research Objectives

Remanufacturing building materials to be environmentally friendly starts with figuring out how to lessen their negative effects. Studying the adverse consequences of paint and cement ingredients on the environment was the primary goal of this article. The purpose herein is to perform a life cycle assessment for the constituents of cement and paint as two widely vast used construction material to determine the appropriate percentages of pollutants in those materials. By doing so, the environmental impacts of those materials could decrease, improving their environmental characteristics and making them more sustainable. In this work, two different simulation tools (GaBi and Open-LCA) were used to carry out the life cycle evaluation of building materials mainly for paint and cement.

2. Methodology

2.1 Assessment and Software

A life cycle assessment is conducted for any product in order to know the environmental effects of this product, and then to determine how to address these effects by studying the different chemical compositions of the product to determine the best one environmentally based on the life cycle assessment procedure.

2.3 Life Cycle Assessment

State-of-the-art research on life cycle assessment (LCA) applied to buildings was reviewed by Abdulrahman *et al.*, [12]. Additionally, they contended that people might lessen and even positively influence how their structures affected the environment, which would lessen the effects of climate change. A new generation of model-based, continually learning LCA tools and procedures that were based on real-time data could accomplish this.

The efforts of Cecilia *et al.*, [13] to measure plastic pollution, describe and estimate the extent of exposure, and assess the effects on human and environmental health are still ongoing. An emitter perspective was provided by Life Cycle Assessment (LCA). This study looked at the methods currently in-use for collecting and reporting data from field and lab studies on the impacts of exposure to micro- and nanoplastics (MNPs) and how those findings relate to LCA data inputs.

2.4 Environmental Impacts

Due mostly to material decisions, the manufacturing and construction sectors have historically contributed significantly to global CO_2 emissions. Concrete and steel are two of the most widely utilized building materials, yet it has been shown that these sectors contribute significantly to atmospheric CO_2 emissions. Consequently, it is becoming more and more crucial to use less of these materials and to discover substitutes that both minimize emissions and satisfy the engineering specifications of a design [14].

2.5 Life Cycle Assessment using Different Software's

GaBi and open LCA are two simulating software used by researchers in studying the different construction material impacts on the environment. Olaniyan *et al.*, [15] assessed the management of the MSW in Oyo Township using GaBi6 Software through the CML and TRACI methods and these comparisons were carried out from impact measurement of: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), and Ozone layer Depletion Potential (ODP). According to the comparisons, the landfilling scenario was the more environmentally preferable and was most effective way to handle solid waste in a sustainable manner using GaBi simulating tool. OpenLCA software, a cradle to gate life cycle assessment (LCA) tool was used to study formaldehydes which is one of the mostly used element as a particle board binder and is one of the largest environmental worries which might produce substances that are carcinogenic to humans. The apparatus used was the Fourier-transform infrared spectroscopy (FTIR) system. Contaminations showed up on the air, water, and soil determines a product's life cycle [16].

2.6 Building Materials

Each building material has compositions that differ from one study to another, and each composition of the same building material has its own environmental effects. These raw materials composition may affect several elements and the following discuss the most used material through the construction projects.

2.6.1 Cement

Cement raw materials are limestone and quarries, and cement factories convert them into cement blocks (clinker) through thermal reaction, and the cost of raw materials represents about 10% to 25% of the total cost of cement production in Egypt. The cement industry in Egypt requires two types of energy: electrical and thermal. Dunuweera *et al.*, [17] said that there are different types of cement products as shown in Table 1. Emissions of greenhouse gases and other environmental pollutants are linked to cement production operations. Given that the cement sector is one of the largest emitters of CO_2, it is appropriate to focus on various CO_2 capture strategies.

Table 1
Composition of components as wt.% used to make different types of cements

Component	Portland-cement (%)	Siliceous-fly ash (%)	Calcareous-cement (%)	Slag-cement (%)	Fume-silica (%)
SiO_2	21.9	52	35	35	85-97
Al_2O_3	6.9	23	18	12	0
Fe_2O_3	3.9	11	6	1	0
CaO	63	5	21	40	<1
MgO	2.5	0	0	0	0
SO_3	1.7	0	0	0	0

Regarding the sustainability of concrete, two primary approaches were commonly deliberated.: (1) the decrease in natural raw material use and (2) the decrease in emissions associated with the manufacture of concrete. The outcomes demonstrated how using fine recycled aggregate in place of natural sand had a favorable environmental impact. In certain situations, the potential for climate change might be reduced by about 40% [18].

2.6.2 Paint

The polymers that are most frequently utilized in the paint and coatings industry are acrylic resins. The majority of acrylic paints are solvent- or water-based. Methyl and butyl methacrylate are two examples of the many forms and combinations of common acrylic polymers.

Table 2
Components of different types of paints by percentage

Component	**WN-RU (%)**	**GA-RU (%)**	**GR-RU (%)**	**WN-BU (%)**	**GA-BU (%)**	**GR-BU (%)**	**SP-BU (%)**
Fe	16.3	29.9	35.3	34.4	38.7	31.1	25.8
Mn	6.5	3.2	6.6	7.1	6.2	11.6	5.6
Ca	15	1.1	15.8	2.6	2.2	1.8	2.1
Si	4.8	16.5	7	9.6	12.6	13.5	17.1
K	0.3	0.8	0.4	0.5	0.5	0.9	1.2
S	0.8	0.3	0.2	0.9	0.3	0.1	0.2
P	2.7	0.6	0.6	0.9	0.7	0.6	0.7
Ti	0.1	0.3	0.1	0.1	0.1	0.1	0.1
Cl	0.1	0.1	0.1		0.1	0.1	0.1
Al	3.8	8.1	2.1	5.1	3	3.8	5.7
Mg	13.9	0.8	1.2	4.5	1.7	1.7	1.5
Na	0.3	0.2	0.3	0.3	0.4	0.5	2.4
Zn		0.1				0.1	
V			0.1				0.1
O	35.5	38.1	30.4	34.1	33.6	34.7	37.7

The raw and burnt umber pigments found in manufactured painters' oil paints from the 20th century are thought to be earth-based natural pigments made from the fusion of manganese and iron oxides. Specifically, manganese is recognized for its ability to act as a main drier and siccative on oil paint films. As indicated in Table 2, dried films from raw and burnt umber oil paints manufactured by Winsor & Newton (UK), Grumbacher (USA), Gamblin (USA), and Speedball (USA) were examined. Stress-strain curves were produced after tensile testing were conducted. The chemical makeup and mechanical characteristics of the oil paint films varied significantly, according to the results [19].

Because kaolin has a high silica and alumina content, it could be used to make paint at a lower cost than titanium dioxide. This replacement could be advantageous for the coating and paint industries. The findings offered compelling evidence in favour of using kaolin pigments derived from renewable resources as a very fine particle material combined with another substance to enhance paint characteristics and reduce environmental effect [20].

2.7 Life Cycle Assessment Software's Comparison

Life cycle assessment has many methodologies and softwares and from the overview presented in Table 3, the user can get more insights for the LCA programs and software.

Table 3
Different software's which used for conducting life cycle assessment

Software	Eco-chain Mobius	Eco-chain Helix	GaBi	One-click-lca	Open-LCA	Sima-Pro
Usability	Beginner	Average	Average to hard	Average to hard	Average to hard	Average to hard
Free Trial	Fourteen day free trial	Not available, demo is offered	Thirty days free trial	Fourteen day free trial	Completely free software	Not available, a demo version available
Cloud-Applications	√	√	X	√	X	X
URL	www. ecochain.com/solutions/helix/	www.ecochain.com/solutions/mobius	www.gabi-software.com	https://www.oneclicklca.com/	http://www.openlca.org/	https://simapro.com/

3. Results

A group of cement mixtures was obtained as presented in table 4 below; in which calcium oxide CaO was the main raw material among the raw materials constituting cement, as it has the largest percentage in the cement mixture and therefore has the largest contribution to each environmental impact.

On the other side, a group of paint mixtures was obtained as presented in table 5 below; in which the number of raw materials varies from one mixture to another, and each mixture has raw materials that differ from the other mixture, and the same or more raw material can be present in more than one mixture, but the number of raw materials remains one of the main factors that affect the number of environmental impacts.

Table 4
Chemical composition of the cement and proposed scenarios for the study

Raw material	S1	S2	S3	S4	S5	S6	S7
Calcium oxide (CaO)	46	47.5	53.9	58.1	63.5	66.4	71.6
Sodium oxide (Na_2O)	0.1	0.1	0.6	0.4	0.1	0.4	0.1
magnesium oxide (MgO)	2.8	3	1.2	1	0.5	0.3	1.1
Aluminum oxide (Al_2O_3)	15.2	21.9	28.9	33.8	2.1	2.7	1
Silicon dioxide (SiO_2)	3.5	3.6	4.3	4.6	31.5	31.1	25.2
phosphorus pentoxide (P_2O_5)	0	0	0	0	0.2	0	0.2
sulfur trioxide (SO_3)	0	0	0	0	0.1	0	0
Potassium oxide (K_2O)	0.2	0.2	4	0.5	0.9	0.5	0.1
Titanium dioxide (TiO_2)	1.7	1.6	0.5	0.6	0.2	0	0
manganese oxide (MnO)	0.7	0.7	0	0	0	0	0
Iron oxide (Fe_2O_3)	29.8	21.4	6.6	1	0.9	1.5	0.7

Table 5
Chemical composition of the paint and proposed scenarios for the study

Raw material	S1	S2	S3	S4	S5	S6	S7
goethite (FeO-OH)	18.9	7.7	14	0	0	0	10.3
manganese oxides (Mn3O4)	11.7	0	0	11	0	0	9
magnesium silicate (Mg2SiO4)	19.3	0	9.2	0	0	8.2	0
calcite (CaCO3)	6.9	3.6	7.3	5.6	4.8	3.5	2.9
dolomite (CaMg(CO3)2)	15.4	0	0	12.1	0	0	7
calcium phosphate (Ca3(PO4)2)	22.1	0	21.5	0	0	10.1	8.6
iron oxide (Fe2O3)	0	14.5	26.9	0	0	0	0
pyrolusite (MnO2)	0	4.9	8.9	4.6	0	13.7	0
kaolinite (Al2Si2O5(OH)4)	0	12.6	0	0	0	0	0
illite (K,H3O)(Al,Mg,Fe)2(Si,Al)4O10(OH)2(H2O)	0	36.7	0	0	0	0	0
potassium magnesium silicate (K2(MgSi5O12))	0	18.5	0	0	0	0	0
sodium aluminum silicate (AlNa12SiO5)	0	0	11.5	0	0	0	0
hematite (Fe2O3)	0	0	0	38.7	13.6	34.3	19.8
quartz (SiO2)	0	0	0	12.4	5.9	4.4	0
spinel (MgAl2O4)	0	0	0	13	5.9	0	0
maghemite (Fe2O3)	0	0	0	0	13.6	0	0
magnetite (Fe3O4)	0	0	0	0	20	0	0
another manganese oxides (Mn2O7)	0	0	0	0	12.2	0	0
mullite (Al6Si2O13)	0	0	0	0	21.9	0	0
anorthoclase (Na,K)AlSi3O8	0	0	0	0	0	20.4	0
wollastonite (CaSiO3)	0	0	0	0	0	5.8	0
sanidine (K,Na)(Si,Al)4O8	0	0	0	0	0	0	24
silicon dioxide (SiO2)	0	0	0	0	0	0	4.2

anorthite ($CaAl_2Si_2O_8$)	0	0	0	0	0	0	14
Others	5.4	1.6	0.9	2.7	2.1	0.4	0.5

After entering the data of all the raw materials which were the quantity of the used raw material and quantity of all pollutants that affect the used raw material (The quantity of each pollutant was entered according to Ali *et al.*, [2]. An assessment of the life cycle of the building material like ceramic, cement, and paint was performed using openLCA and GaBi software's for different mixtures. This was then followed by a Comparison of the environmental impacts which were calculated using values of ceramic, cement, and paint pollutants in Egypt for a group of mixtures.

3.1 Impacts of Different Samples of Cement and Paint Mixtures

Only a specific set of environmental impacts—namely, eutrophication, acidification, global warming, climate change, and human toxicity—have been noted, as the data that are now accessible only address these impact categories and do not address other effect categories. The value of global warming exceeds that of climate change because the former refers to the increase in Earth's surface temperature brought on by human-caused increases in carbon dioxide and other greenhouse gas concentrations from burning coal and oil, while the latter also includes the effects of global warming, such as melting glaciers and rainstorms, which cause temperatures to drop and ultimately cause climate change. On the contrary, the factors of equations for calculating the rest of the impact categories largely correspond.

3.1.1 Impact categories of cement samples

A comparison was made between the impacts of different samples of cement and paint to obtain the highest and lowest values that could adversely affect the environment and contribute to global warming and hence climatic changes. Figure 1 shows cement samples results according to the two software.

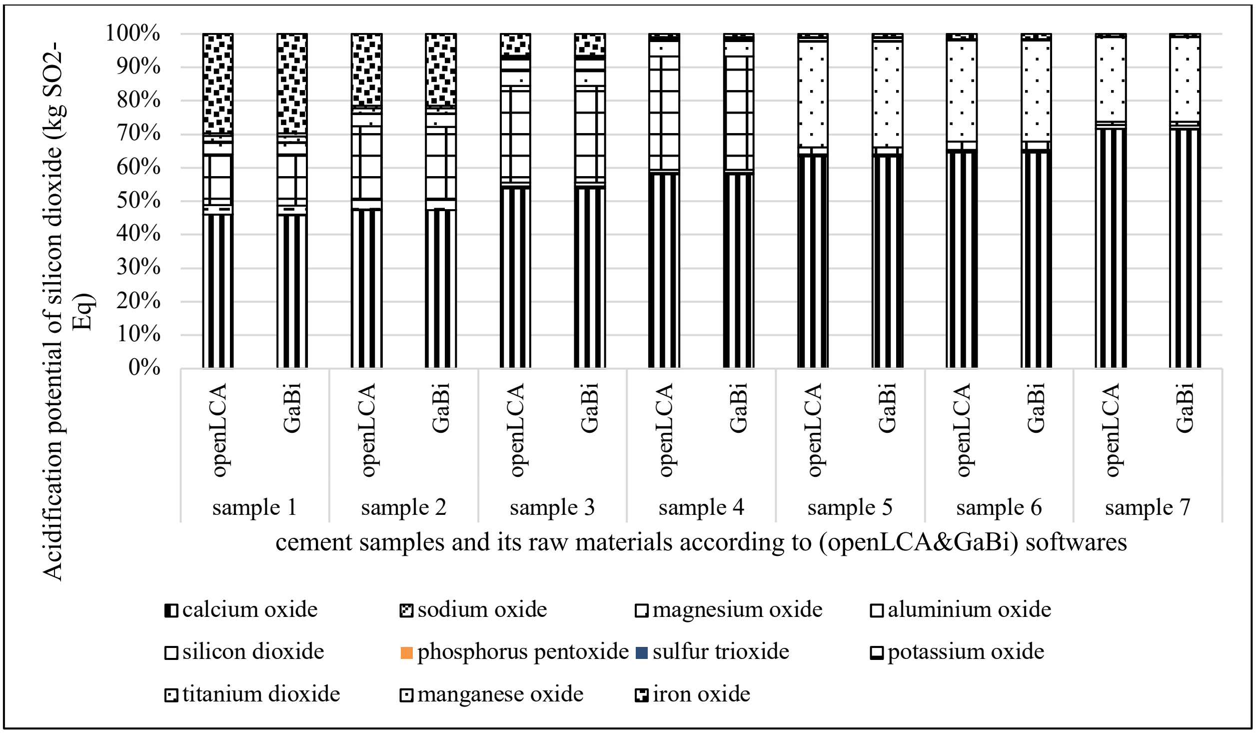

Fig. 1. Acidification potential (kg SO_2-Eq)

Table 6
Acidification caused by calcium oxide in different cement samples

Software	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
OpenLCA	3.19	3.29	3.735	4.025	4.4	4.6	4.96
GaBi	3.19	3.29	3.74	4.03	4.4	4.6	4.96

The highest acidification was 4.96 kg SO_2-Eq and 4.96 kg SO_2-Eq from openLCA and GaBi respectively at percentage 71.6% calcium oxide of Sample 7 and the lowest acidification was 3.19 kg SO_2-Eq and 3.19 kg SO_2-Eq from openLCA and GaBi respectively at percentage 46% calcium oxide of sample 1 as demonstrated in Table 6.

As shown in Figure 2 below and Table 7, the highest climate change was 49.6 kg CO_2-Eq and 95.5 kg CO_2-Eq from openLCA and GaBi respectively at percentage 71.6% calcium oxide of Sample 7 and the lowest climate change was 31.9 kg CO2-Eq and 61.4 kg CO2-Eq from openLCA and GaBi respectively at percentage 46% calcium oxide of sample 1.

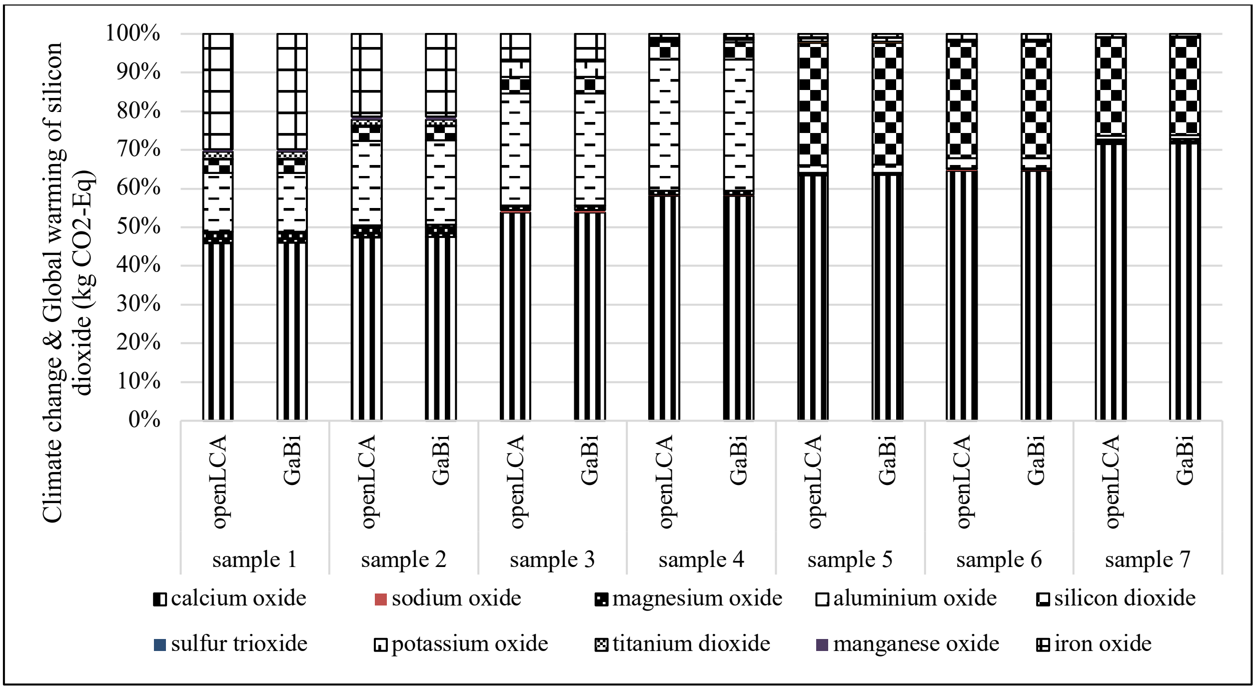

Fig. 2. Climate change and global warming (kg CO_2-Eq)

Table 7
Climate change and global warming caused by calcium oxide in different cement samples

Software	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
OpenLCA	31.9	32.9	37.35	40.25	44	46	49.6
GaBi	61.4	63.4	71.9	77.5	84.7	88.6	95.5

As shown in Figure 3 and Table 8 below, the highest eutrophication was 1.2896 kg PO_4-Eq and 1.29 kg PO_4-Eq from openLCA and GaBi respectively at percentage 71.6% calcium oxide of Sample 7 and the lowest eutrophication was 0.829 kg PO_4-Eq and 0.8294 kg PO_4-Eq from openLCA and GaBi respectively at percentage 46% calcium oxide of Sample 1.

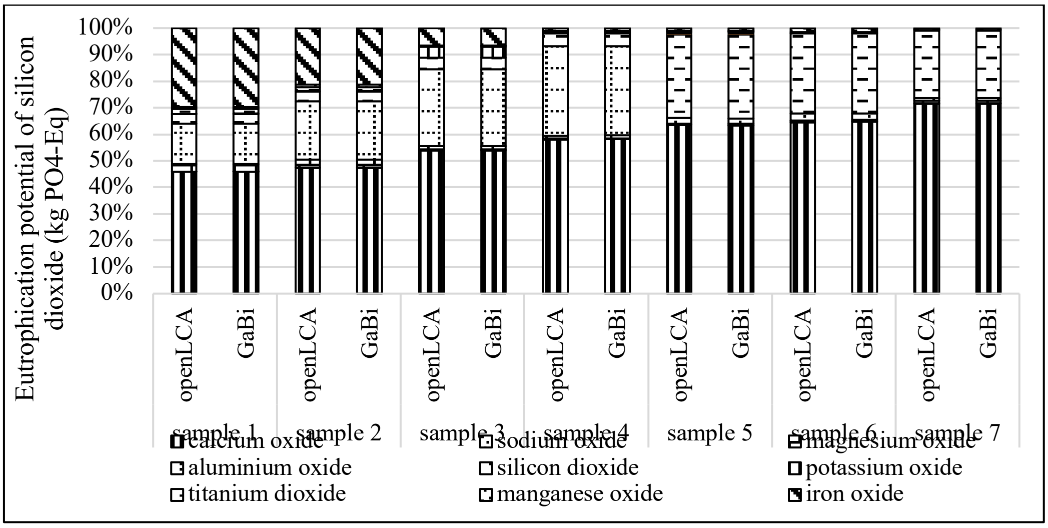

Fig. 3. Eutrophication potential (kg PO4-Eq)

Table 8
Eutrophication caused by calcium oxide in different cement samples

Software	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
OpenLCA	0.829	0.8554	0.9711	1.0465	1.144	1.196	1.2896
GaBi	0.8294	0.855	0.971	1.05	1.14	1.2	1.29

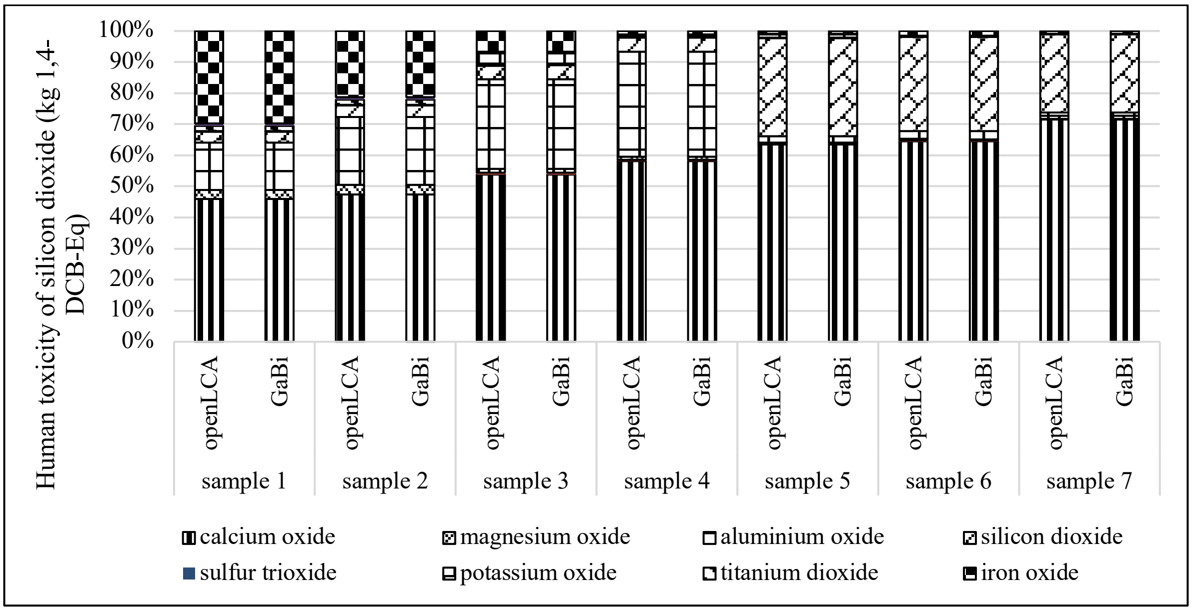

Fig. 4. Human toxicity (kg 1,4-DCB-Eq)

Table 9
Human toxicity caused by calcium oxide in different cement samples

Software	S1	S2	S3	S4	S5	S6	S7
OpenLCA	7.656	7.896	8.964	9.66	10.56	11.04	11.904
GaBi	7.66	7.9	8.96	9.66	10.6	11	11.9

As shown in Figure 4 and Table 9, the highest human toxicity was 11.904 kg 1,4-DCB-Eq and 11.9 kg 1,4-DCB-Eq from openLCA and GaBi respectively at percentage 71.6% calcium oxide of Sample 7 and the lowest human toxicity was 7.656 kg 1,4-DCB-Eq and 7.66 kg 1,4-DCB-Eq from openLCA and GaBi respectively at percentage 46% calcium oxide of Sample 1.

Therefore, working to reduce the percentage of calcium oxide will reduce the environmental impacts of cement on the environment because the highest participations in all impact categories were from it. Reducing the density of the cement with the stability of its mass increases its volume, and therefore a greater number of cement bags can be produced when its density is reduced or vice versa as displayed in Table 10.

Table 10
Impacts of 1 cement bag

used cement:	density	3120	kg/m3
	weight	1000	kg
	weight of cement bag	50	kg
	slab thickness	20	cm
derived properties [21]	volume	0.320512821	m3
	area of covered floor	1.602564103	m2
	approximated area	1.6	m2
	density	624	kg/m2
	number of cement bags	12.48	cement bag/m2
	approximated number of cement bags	12	cement bags
impacts from GaBi and openLCA (due to 1 cement bag)	value of GaBi	value of openLCA	
acidification potential (kg SO2-Eq)	0.577916667	0.5775	
climate change & Global warming (kg CO2-Eq)	11.11333333	5.775	
eutrophication potential (kg NOx-Eq)	0.150208333	0.15015	
human toxicity (kg 1,4-DCB-Eq)	1.385833333	1.386	

3.1.2 Impact categories of paint samples

The impacts of different samples of paint on global warming and hence climatic changes using openLCA and GABI are displayed in the following paragraphs.

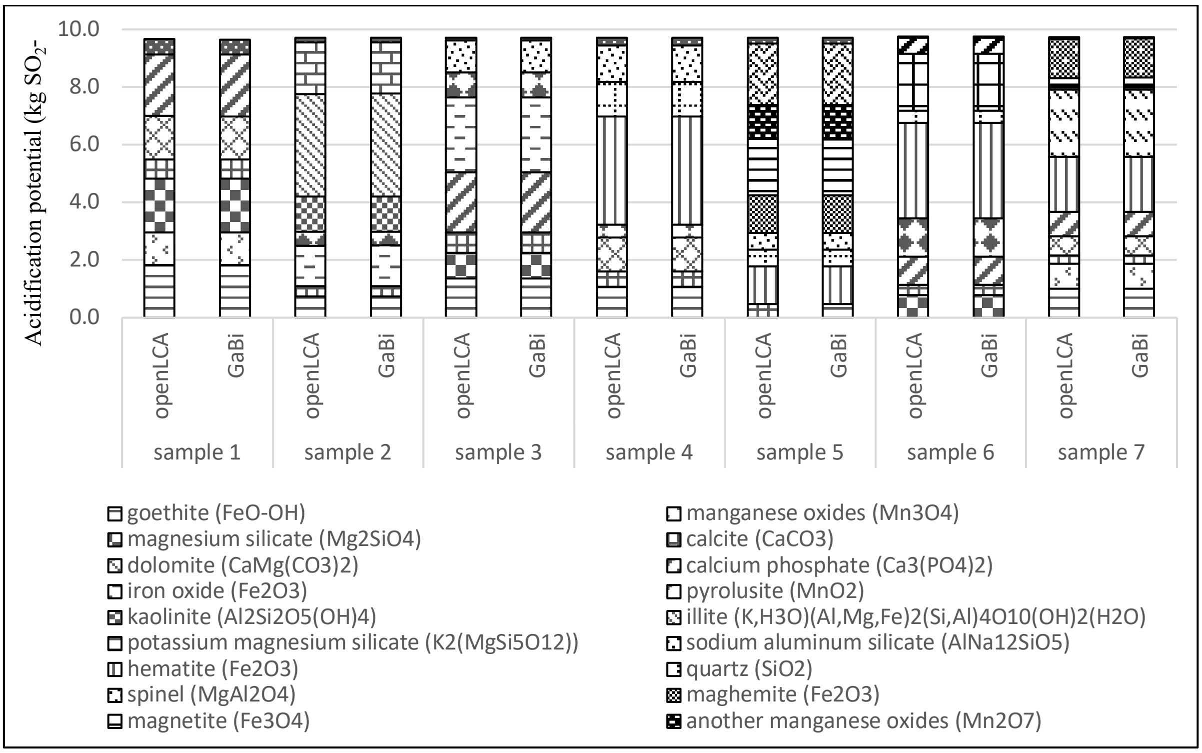

Fig. 5. Acidification potential (kg SO_2-Eq)

From Figure 6 demonstrated below, it shows that Sample 1 had the least acidification (9.6565 kg SO_2-Eq and 9.652 kg SO_2-Eq from openLCA and GaBi respectively) as represented in Figure 5 above and the minimum number of raw materials while sample 6 had the highest acidification (9.7533 kg SO_2-Eq and 9.7498 kg SO2-Eq from openLCA and GaBi respectively) and higher number of raw materials than sample 1, so working to reduce the number of raw materials will reduce acidification of paint on the environment.

In addition, Sample 1 had the least climate change (96.565 kg CO2-Eq and 96.52 kg CO_2-Eq from openLCA and GaBi respectively) as represented also in Figure 6 and the minimum number of raw materials while sample 6 had the highest climate change (97.533 kg CO_2-Eq and 97.498 kg CO_2-Eq from openLCA and GaBi respectively) and higher number of raw materials than sample 1, so working to reduce the number of raw materials will reduce climate change of paint on the environment.

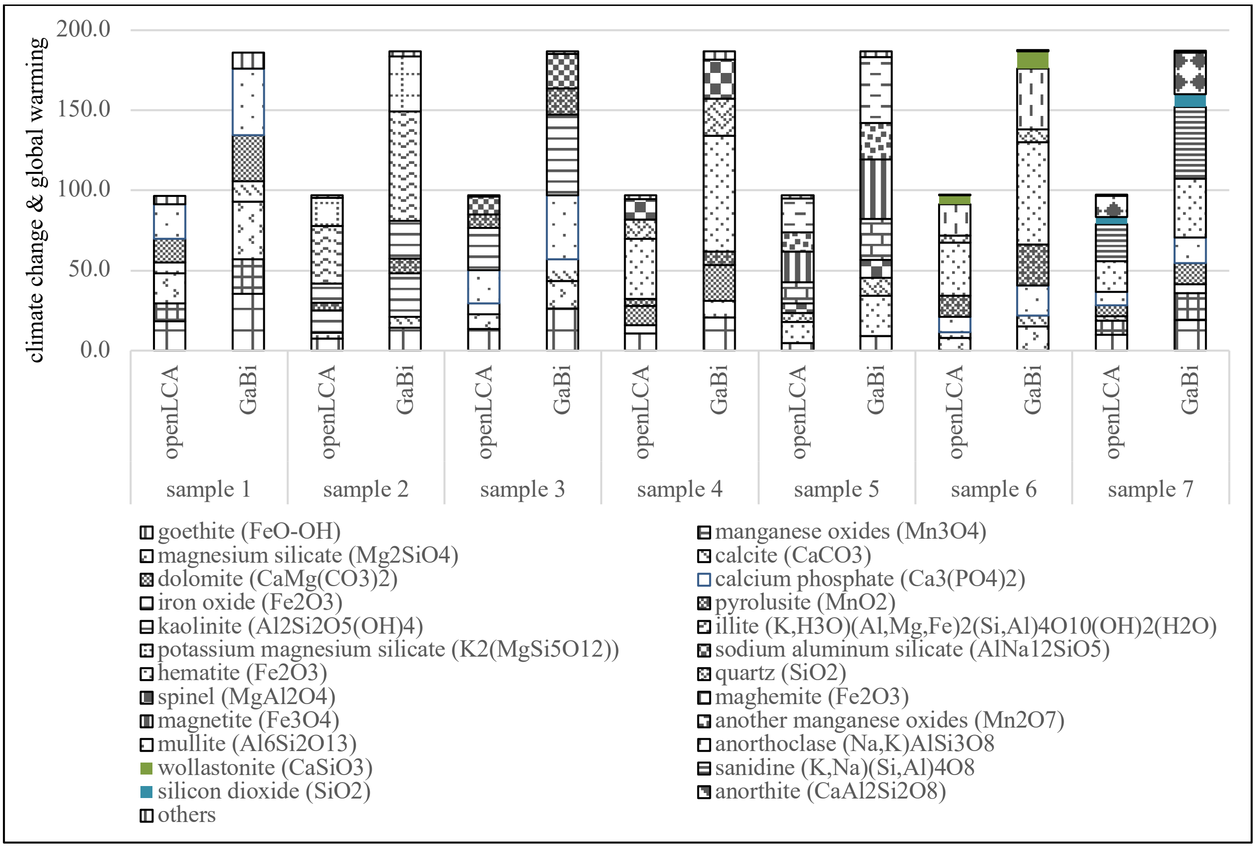

Fig. 6. Climate change and global warming (kg CO2-Eq)

The results for eutrophication is presented in Figure 7. Sample 1 had the least eutrophication (2.5106 kg PO4-Eq and 2.51 kg PO_4-Eq from openLCA and GaBi respectively) as represented in Figure 7 and the minimum number of raw materials while sample 6 had the highest eutrophication (2.5359 kg PO4-Eq and 2.5347 kg PO_4-Eq from openLCA and GaBi respectively) and higher number of raw materials than sample 1, so working to reduce the number of raw materials will reduce eutrophication of paint on the environment.

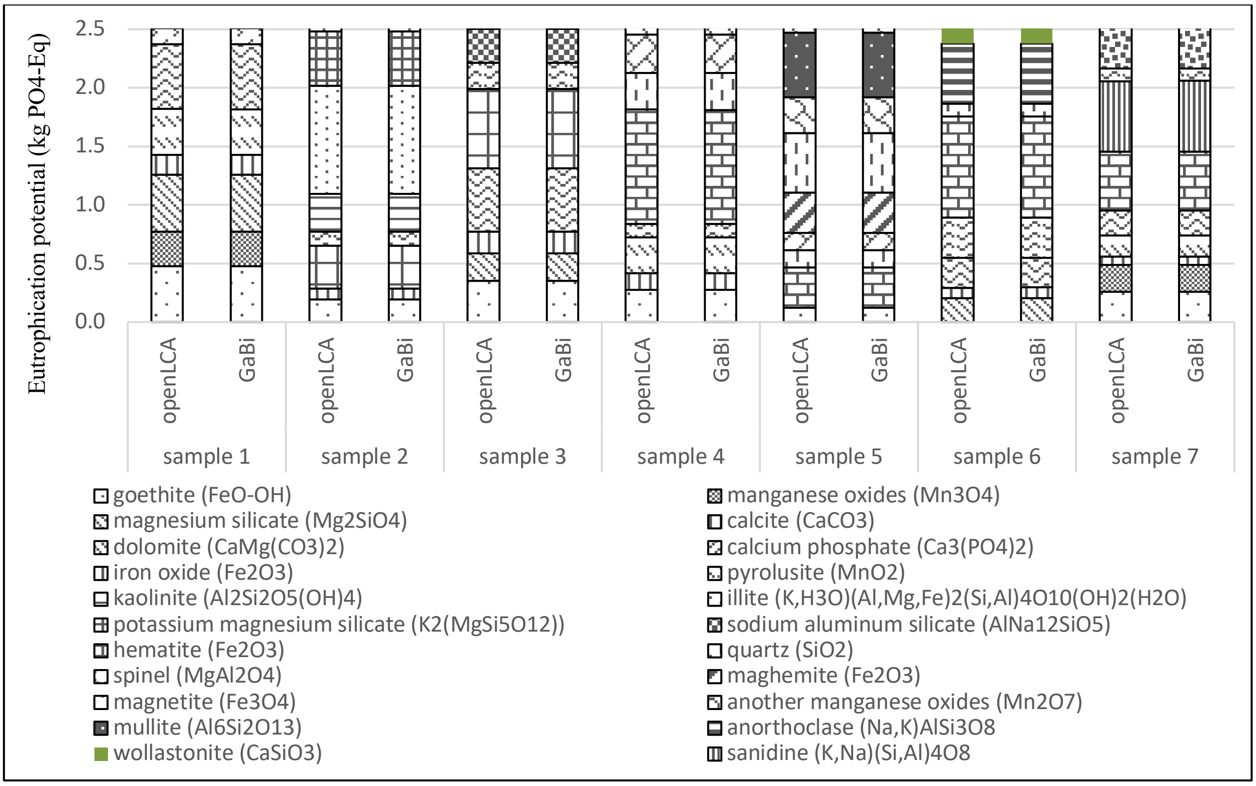

Fig. 7. Eutrophication potential (kg PO4-Eq)

Figure 8 displays the results for the impact on human toxicity. Results show that sample 1 had the least human toxicity (23.1751 kg 1,4-DCB-Eq and 23.19 kg PO_4-Eq from openLCA and GaBi respectively) as represented in Figure 8 and the minimum number of raw materials while sample 6 had the highest human toxicity (23.4079 kg 1,4-DCB-Eq and 23.4111 kg PO_4-Eq from openLCA and GaBi respectively) and higher number of raw materials than sample 1, so working to reduce the number of raw materials will reduce human toxicity of paint on the environment.

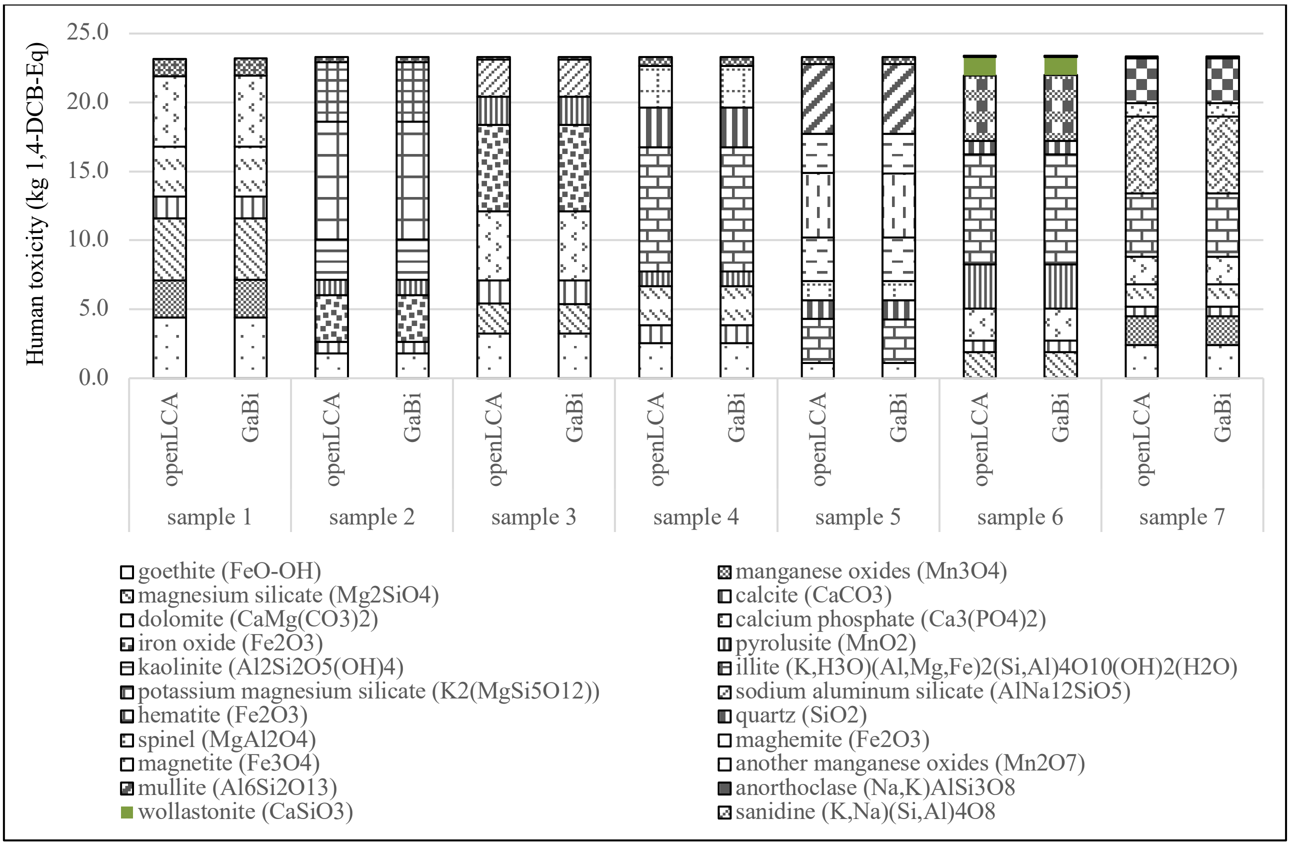

Fig. 8. Human toxicity (kg 1,4-DCB-Eq)

On the other side, calcium phosphate had the highest acidification in sample 1 (2.1398 kg SO_2-Eq and 2.14 kg SO_2-Eq from openLCA and GaBi respectively), illite had the highest acidification in sample 2 (3.557 kg SO2-Eq and 3.56 kg SO_2-Eq from OpenLCA and GaBi respectively), iron oxide had the highest acidification in sample 3 (2.6091 kg SO_2-Eq and 2.61 kg SO_2-Eq from openLCA and GaBi respectively), hematite had the highest acidification in sample 4 (3.7484 kg SO_2-Eq and 3.75 kg SO2-Eq from openLCA and GaBi respectively), mullite had the highest acidification in sample 5 (2.1184 kg SO2-Eq and 2.12 kg SO_2-Eq from openLCA and GaBi respectively), hematite had the highest acidification in sample 6 (3.3211 kg SO_2-Eq and 3.32 kg SO_2-Eq from openLCA and GaBi respectively), and sanidine had the highest acidification in sample 7 (2.3293 kg SO_2-Eq and 2.33 kg SO_2-Eq from openLCA and GaBi respectively).

Calcium phosphate had the highest climate change and global warming in sample 1 (21.3975 kg CO_2-Eq and 41.2 kg CO_2-Eq from openLCA and GaBi respectively), illite had the highest climate change and global warming in sample 2 (35.5695 kg CO2-Eq and 68.5 kg CO_2-Eq from openLCA and GaBi respectively), iron oxide had the highest climate change and global warming in sample 3 (26.0905 kg CO_2-Eq and 50.2 kg CO_2-Eq from openLCA and GaBi respectively), hematite had the highest climate change and global warming in sample 4 (37.4835 kg CO_2-Eq and 72.1 kg CO_2-Eq from openLCA and GaBi respectively), mullite had the highest climate change and global warming in sample 5 (21.1835 kg CO_2-Eq and 40.8 kg CO_2-Eq from openLCA and GaBi respectively), hematite had the highest climate change and global warming in sample 6 (33.2105 kg CO2-Eq and 63.9 kg CO_2-Eq from openLCA and GaBi respectively), and sanidine had the highest climate change and global warming in sample 7 (23.293 kg CO_2-Eq and 44.8 kg CO_2-Eq from openLCA and GaBi respectively).

Calcium phosphate had the highest eutrophication in sample 1 (0.5563 kg PO_4-Eq and 0.556 kg PO_4-Eq from openLCA and GaBi respectively), illite had the highest eutrophication in sample 2 (0.9248 kg PO4-Eq and 0.925 kg PO4-Eq from openLCA and GaBi respectively), iron oxide had the highest eutrophication in sample 3 (0.6784 kg PO4-Eq and 0.678 kg PO4-Eq from openLCA and GaBi respectively), hematite had the highest eutrophication in sample 4 (0.9746 kg PO_4-Eq and 0.975 kg PO_4-Eq from openLCA and GaBi respectively), mullite had the highest eutrophication in sample 5 (0.5508 kg PO_4-Eq and 0.551 kg PO4-Eq from openLCA and GaBi respectively), hematite had the highest eutrophication in sample 6 (0.8635 kg PO4-Eq and 0.863 kg PO4-Eq from openLCA and GaBi respectively), and sanidine had the highest eutrophication in sample 7 (0.6056 kg PO4-Eq and 0.606 kg PO_4-Eq from openLCA and GaBi respectively).

Calcium phosphate had the highest human toxicity in sample 1 (5.1354 kg 1,4-DCB-Eq and 5.14 kg 1,4-DCB-Eq from openLCA and GaBi respectively), illite had the highest human toxicity in sample 2 (8.5367 kg 1,4-DCB-Eq and 8.54 kg 1,4-DCB-Eq from openLCA and GaBi respectively), iron oxide had the highest human toxicity in sample 3 (6.2617 kg 1,4-DCB-Eq and 6.26 kg 1,4-DCB-Eq from openLCA and GaBi respectively), hematite had the highest human toxicity in sample 4 (8.996 kg 1,4-DCB-Eq and 9 kg 1,4-DCB-Eq from openLCA and GaBi respectively), mullite had the highest human toxicity in sample 5 (5.084 kg 1,4-DCB-Eq and 5.08 kg 1,4-DCB-Eq from openLCA and GaBi respectively), hematite had the highest human toxicity in sample 6 (7.9705 kg 1,4-DCB-Eq and 7.97 kg 1,4-DCB-Eq from openLCA and GaBi respectively), and sanidine had the highest human toxicity in sample 7 (5.5903 kg 1,4-DCB-Eq and 5.59 kg 1,4-DCB-Eq from OpenLCA and GaBi respectively).

Table 11
Properties and impacts of 1 m^2 painting production

Painting properties [22]	Density (kg/m^3)	1200
	Weight (kg)	1000
	assumed wall painting rate (m^2/L)	12
	assumed volume of one packets (L)	10
Derived properties	Volume of packets (L)	833.33
	no. of packets (unit)	83.33
	Total wall area (m^2)	10000
Impacts due to 1 m^2 paint	GaBi	OpenLCA
Acidification Potential (kg SO2-Eq)	0.0009652	0.0009656
Climate change & Global warming (kg CO_2-Eq)	0.0186	0.009656
Eutrophication potential (kg NOx-Eq)	0.000251	0.000251
Human toxicity (kg 1.4-DCB-Eq)	0.002319	0.002317

Reducing the density of the paint with the stability of its mass increases its volume, and therefore a greater area of paint can be produced when its density is reduced or vice versa.

4. Conclusions

The life cycle assessment of building materials is crucial since the ingredients used in the manufacturing process have numerous negative effects. As a result, it's critical to reject the large amount of raw materials that have a significant influence. This study investigated the constituents of cement and paint that adversely have negative impact on the surrounding environment, and which are considered two widely used construction building materials. Two sophisticated software programs, GaBi and OpenLCA, were used to conduct the life cycle assessment for cement and paint. The findings indicated that lowering the percentage of calcium oxide and silicon dioxide in cement mixture as well as the raw materials in paint mixtures, will less stress on the environment. Furthermore, the study clarifies the viability of the suggested approach and identifies the least impactful mixtures, which included raw materials from sample 1 to be used in Egyptian paint and cement mixtures, and silicon dioxide percentages of 51.14% (mixture 1) and 71.6% (mixture 7) respectively.

The study's recommendation is to examine the samples' strength and quality, by altering the raw materials composition in order to determine whether or not the samples can be implemented, attain the desired level of environmental quality, and reduce any negative effects on the environment.

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