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DESIGN OF SOFTWARE FOR SELF-ASSESSMENT OF RISKS AND ENVIRONMENTAL IMPACTS

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Background: The environment is subject to multifaceted aggressions. Industrial activities as well as the underlying processes generate various types of pollutants and waste causing increased levels of pollution. Large-scale mining is known to have negative impacts on water and soil quality, which is accompanied by significant changes in the composition of surface waters and soils due to their pollution with heavy metals, sulphates and other hazardous compounds. Unfortunately, in developing countries, there is generally no or low level of regulation (control) of mining activities, which are often carried out using outdated methods and basic tools and are accompanied by enormous environmental and social problems. Cameroon is rich in deposits of iron ore, gold, granite, sand, gravel, and other minerals, which contributes to the development of numerous large-scale mining operations across the country. To reduce the adverse impacts of mining activities on the health of the population and workers at these enterprises, it is critical to have up-to-date information on environmental degradation and to assess the risks and consequences for their prevention. **Objectives:** This study aims to design a computer tool to support companies in their environmental management, in particular software for self-assessment of environmental risks and impacts based on empirical methods, which work offline, free and completely free, to improve their environmental performance. Due to the fact that Granulats du Cameroun (GRACAM) is a leader in the aggregates industry and an example of environmental responsibility, this company was chosen as the subject of the study. The managerial interest of such a study is to show how IT tools facilitate the environmental management process, while reducing costs. These tools are still not widespread and considerable research and development work remains to be done in this area. **Methods:** The preliminary risk analysis method and the Fecteau matrix were integrated into the GRIENV software for the assessment of risks and environmental impacts respectively. **Results:** In current case study, 15 risks were assessed for 13 aspects and only 1 is acceptable and the other 14 require urgent action, which makes a percentage of more than 93% (detailed information on the identified risks is not provided because the company did not give consent). This results in the absence of an environmental management plan. The absence of a real environmental management plan would be one of the components responsible for 78.6% of this major and average importance of the 15 impacts assessed. **Conclusion:** The study achieved its goal by introducing and testing a new computer tool, GRIENV, to support companies in environmental management, specifically software for self-assessment of environmental risks and impacts based on empirical methods, with the goal of improving their environmental performance. Testing the developed GRIENV software application allowed for risk assessments at real workplaces within an operating enterprise in just a few hours, compared to the several days required with manual application. GRIENV is an effective solution because it delivers relevant results within an optimal timeframe.

Keywords: environmental impact; environmental risk; environmental management; environmental performance; software.

INTRODUCTION

The environment is subject to multifaceted aggressions. Industrial activities as well as the underlying processes generate various types of pollutants and waste causing increased levels of pollution.

Large-scale mining is known to have negative impacts on water and soil quality, which is accompanied by significant changes in the composition of surface waters and soils due to their pollution with heavy metals, sulphates and other hazardous compounds; changes in the particle size distribution and colour of the topsoil; loss of vegetation cover and the formation of large quarries; numerous river diversions (Sylvie et al., 2024; Mutika et al., 2024; Blanche et al., 2024; Yiika et al., 2023; Tehna et al., 2019). Unfortunately, in developing countries, there is generally no or low level of regulation (control) of mining activities, which are often carried out using outdated methods and basic tools and are accompanied by enormous environmental and social problems.

Populations living in mining areas of Cameroon are exposed to the risk of exposure to the metallic elements Cr, Cd, Pb, Co, Fe, Zn, and Mn due to the high mobility, bioavailability, and reactivity of these elements through contaminated aquatic environments and soil. Recent studies report that Cr currently poses no significant health hazard as it does not exceed permissible limits, while Cd, Pb, As, and Hg pose a real hazard and pose high environmental risks to the population of Cameroon (Yiika et al., 2023; Sylvie et al., 2024). Studies in Cameroon found that artisanal and semi-mechanized mining contributed to the physical contamination of environmental components with metals, with Fe concentrations being highest and Cd concentrations being lowest, namely: Fe > Pb > As > Hg > Cd. These concentrations were significantly seasonally dependent (Ayiwouo et al., 2022). Alkaline pH values in contaminated areas exacerbate risks to aquatic organisms, although complete destruction is not observed (Mutika et al., 2024). Image classification of mining areas showed a decrease in vegetation cover by 11.74% over 5 years (Mbale, Uganda), an increase in bare soil area by 9.2%, and an increase in exploitable area by 5.4%. Diversion of the main river channel was also detected (Blanche et al., 2024; Yiika et al., 2023; Tehna et al., 2019).

Cameroon is rich in deposits of iron ore, gold, granite, sand, gravel, and other minerals, which contributes to the development of numerous large-scale mining operations across the country. In the industrial sector, sand is a key component in the production of glass and silicon products for the electronics industry (Kagonbé et al., 2024). Sand and gravel are the most frequently mined materials due to their direct use in construction for infrastructure development, which is particularly relevant due to the increasing urbanization of the population. Moreover, urbanization is a significant factor contributing to unsustainable mineral extraction and the development of artisanal mining in mining sites in many developing countries, particularly in Cameroon (Kagonbé et al., 2024). Unfortunately, in Cameroon, gravel and sand are extracted by crushing natural rock and from riverbeds, respectively, which involves multiple parties (Kagonbé et al., 2024).

Despite the environmental protection measures implemented, deficiencies still remain, leading to the leakage of toxic effluents into the environment due to leaks from tailings dams and pipeline failures, contributing to increased potential health risks for local communities and, particularly, mining workers (Mutika et al., 2024; Sylvie et al., 2024). Therefore, to reduce the adverse impacts of mining activities on the health of the population and workers at these enterprises, it is critical to have up-to-date information on environmental degradation and to assess the risks and consequences for their prevention (Bell & Foni, 2007).

The word "assessment" also evokes a certain imprecision which turns out to be a reality with regard to environmental risk and impact, given that they mobilize very specific knowledge (chemistry, physics, biology, medicine, ecology, etc.), which are generally not part of the skills expected of decision-makers, which makes the assessment of environmental risks and impacts a complex and tedious task, in terms of time and cost. Technologies such as social media and software facilitate the acquisition of new skills as well as the rapid and decentralized processing of information (Chelo et al., 2021). Modern research increasingly aims to create/use software tools for control and monitoring of the environment or technological processes (Kuripta et al., 2021; Wang et al., 2022). These new technologies thus represent a strategic advantage in environmental management through the dissemination of information, the improvement of employee productivity by reducing the arduousness of work and the improvement of company performance levels in an evolving field where the risk of non-compliance is always present (Desmazes & Lafontaine, 2007). Rapid forecasting of environmental incidents using software helps reduce risks and improve safety in the mining industry. Environmental management software, such as EcoOnline, ProcessMap, Provisoft, EPESME, etc., are web applications that demonstrate this contribution, but these are more or less complex and paid. This study aims to design a computer tool to support companies in their environmental management, in particular software for self-assessment of environmental risks and impacts based on empirical methods, which work offline, free and completely free, to improve their environmental performance.

Granulats du Cameroun (GRACAM) is a leader in the aggregates industry and a model of environmental responsibility. The company's activities include mineral exploration in the country's main mining regions and the operation of a granite quarry. The highly skilled employees at GRACAM provide customers with high-quality products and services, with a genuine commitment to quality workmanship. Environmental responsibility underpins all the company's operations, from raw material extraction to delivery, ensuring minimal environmental impact. To this end, the GRACAM company was designated as our case study. The managerial interest of such a study is to show how IT tools facilitate the environmental management process, while reducing costs. These tools are still not widespread and considerable research and development work remains to be done in this area.

MATERIALS AND METHODS

The world of computing is constantly evolving and the emergence of several programming languages and application development environments that can be run on PCs is a good example. To determine the language and IDE that can best meet the needs of our application, we consulted the usage statistics of these platforms. These statistics show that JavaScript, since its creation in the mid-90s, remains the most popular, followed by Python which occupies second place, despite initially having difficulty gaining its followers, however, PHP remains the easiest to use and completely free. Regarding development environments, PyCharm takes the lead, but Visual Studio Code remains the most popular with 71.06% (Barron, 2021). For the software design, PHP was designated as the programming language and Visual studio code as the integrated development environment, which is ideal for local and web applications, it is also free and supports debugging, syntax highlighting, intelligent code completion. It supports all the languages mentioned above (Alexandra, 2021). The four-phase life cycle was chosen for this work: design, development, testing, generation and deployment (Figure 1).

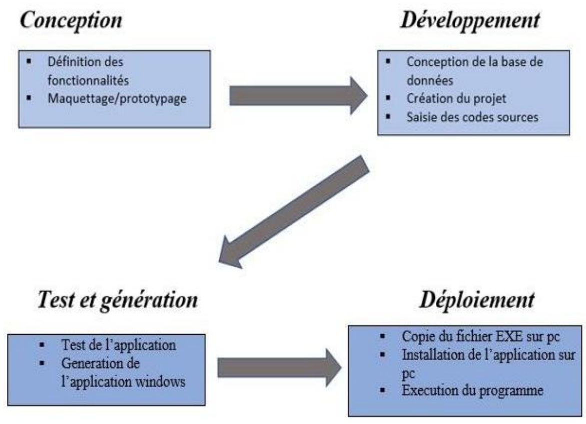


Figure 1. Application development cycle (MonPetitMobile, 2016)

Conception

For the design of the GRIENV software, a class diagram was developed, then the principle of iterative prototyping, which is a key element of iterative design, was designated. It consists of designing intermediate and incomplete versions of software, designed to test the use before the final programming phase. Carried out early enough, Mock-up/prototyping allows usability problems to be detected and functionalities to be verified before full coding. This promotes the optimization of the process and development costs (MonPetitMobile, 2016).

Development of the class diagram

The class diagram provides an abstract representation of the system objects that will interact with the user and with each other. The UML language was used to mock-up the class diagram of the GRIENV software (Figure 2).

Development of mock-ups

The software functionalities are modelled using Mock-ups to visualize its operation and adjust it before development. Figures 3 to 9 represent the start page, homepage, glossary menus, environmental aspects, environmental risks, environmental impacts and ESMP respectively.

Development

This is the coding phase where the developer edits thousands of codes as a code editor, the integrated development environment (IDE) Visual studio Code was preferred, which allows working with languages such as: C#, C++, Python, JavaScript, HTML, PHP, CSS. It is a complete set of development tools, allowing the generation of web applications, desktop applications and mobile applications. These languages can share tools and facilitate the creation of solutions. (Vs code.microsoft.com, visit on 20-04-2022).

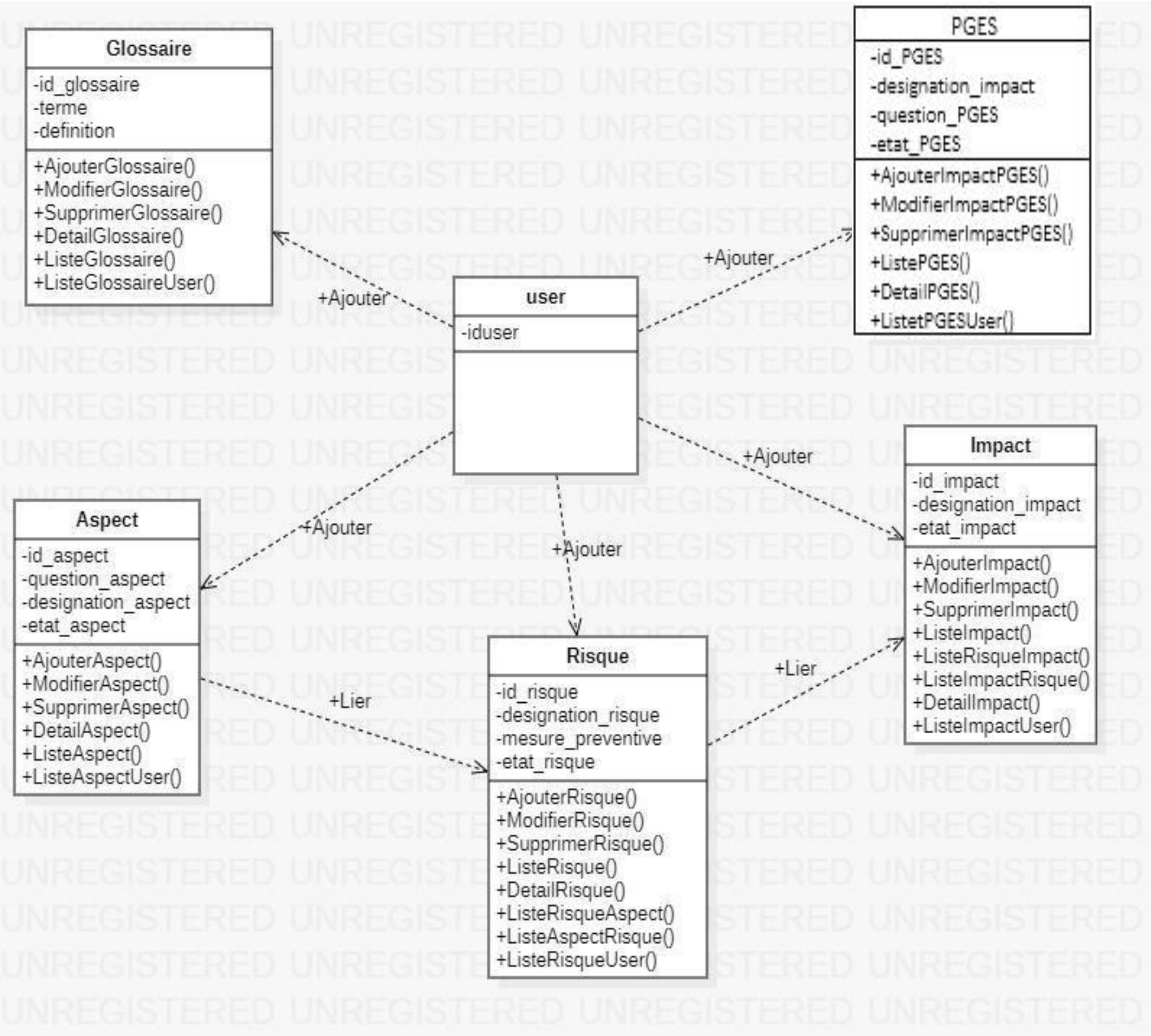
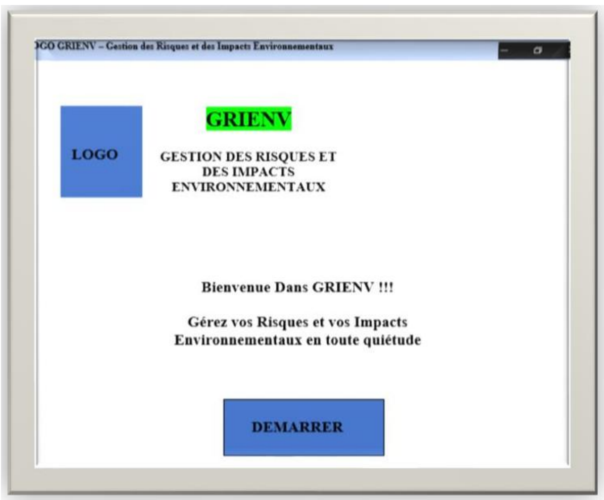


Figure 2. Class diagram



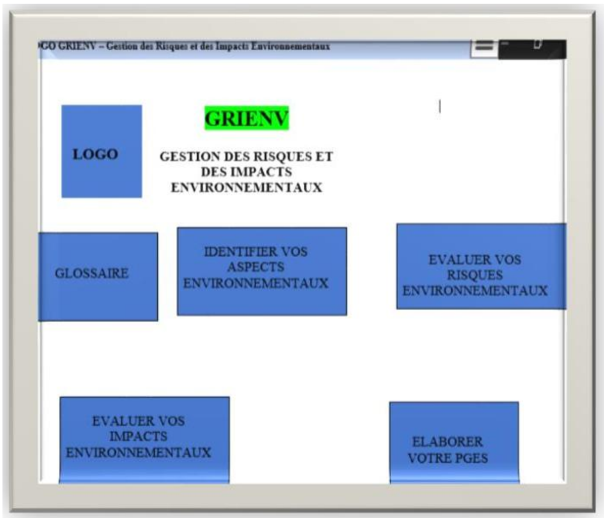


Figure 3. Mock-up of the start page

Figure 4. Mock-up of the homepage

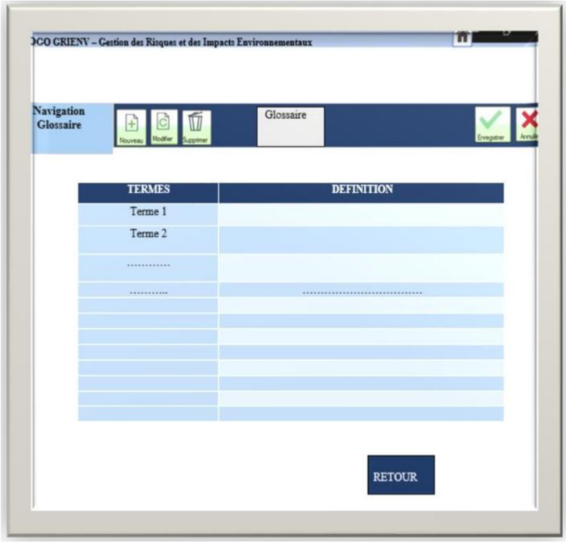


Figure 5. Mock-up of the glossary interface

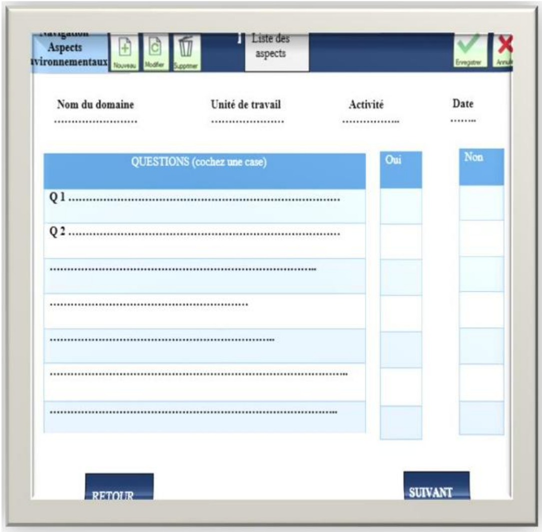


Figure 6. Mock-up of the interface identification of environmental aspects

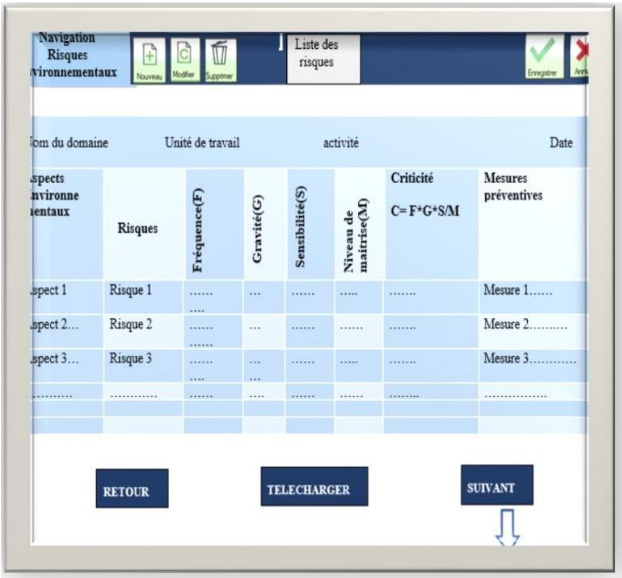


Figure 7. Mock-up of the interface assess environmental risks

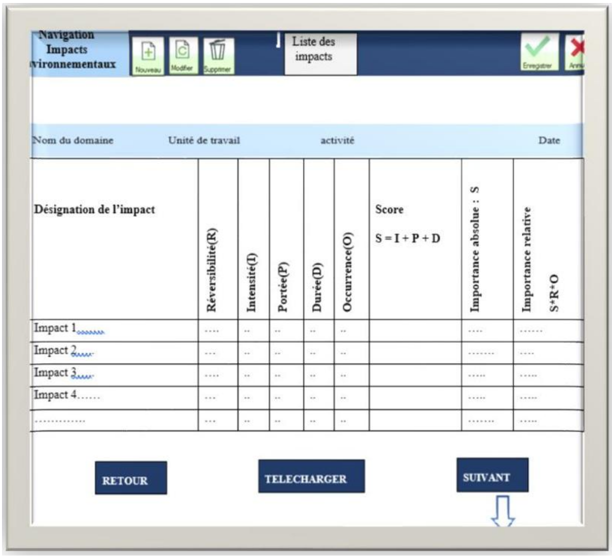


Figure 8. Mock-up of the interface assess environmental impacts

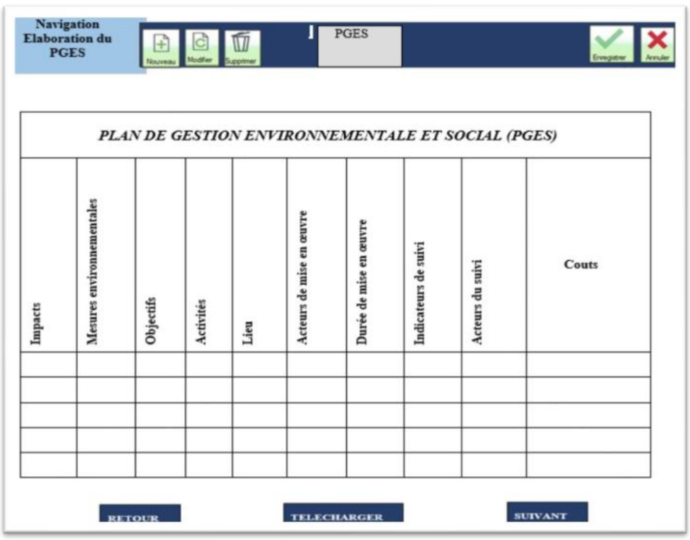


Figure 9. Mock-up of ESMP interface

Deployment

This is the final stage of GRIENV software development, also known as the delivery phase or the 'operational phase'. During this stage, the entire procedure leading to the installation and execution of the software is written to facilitate its installation and use. Finally, a company is designated to implement the software.

RESULTS

The interfaces of the software designed are presented in the form of screenshots, as well as the results of the application of the GRIENV software in the company GRACAM SA, as illustrated by Figures 10 to 19.

The start page

Figure 10 shows the start page of our application, from here the user can consult the user guide by clicking on the menu button or on start to go to the homepage.

Figure 10. Screenshot of the start page

Homepage

The homepage of the GRIENV software contains six buttons, namely: the "GLOSSARY" button which provides access to a number of definitions that will allow the user to understand the terms used within the software; the "IDENTIFY YOUR ENVIRONMENTAL ASPECTS" button which provides access to a series of questions that must be completed by the user; the "ASSESS YOUR ENVIRONMENTAL RISKS" button providing access to the environmental risk assessment grid; the "ASSESS YOUR ENVIRONMENTAL IMPACTS" button which provides access to a De Fecteau matrix for assessing environmental impacts, the "ESMP" button which provides access to the interface for developing an environmental and social management plan. As shown in Figure 11.

Figure 11. Screenshot of the homepage

Glossary interface

Figure 12 presents a series of terms and definitions from the lexical field of the environment. The “NEW” and “SAVE” functionalities allow you to enter and save new terms in the software. Here you can see the definition of environmental aspect, environment, assessment, etc.

Interface identify your environmental aspects

Figure 13 represents the interface containing a series of questions to which the user must answer "yes" or "no" to determine the environmental aspects that prevail within his structure.

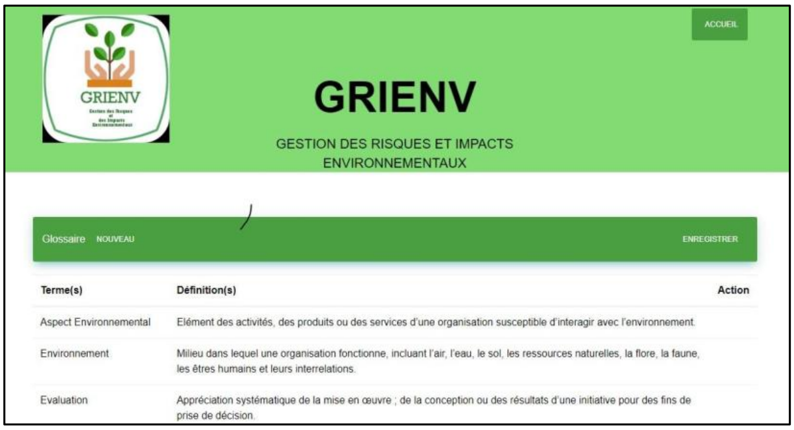


Figure 12. Screenshot of the glossary interface

Figure 13. Screenshot of the interface to identify your environmental aspects

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Interface to identify significant environmental aspects

On this interface, the user will be able to choose the aspects on which priority is given before others, to quickly reduce the risks and environmental impacts of high importance.

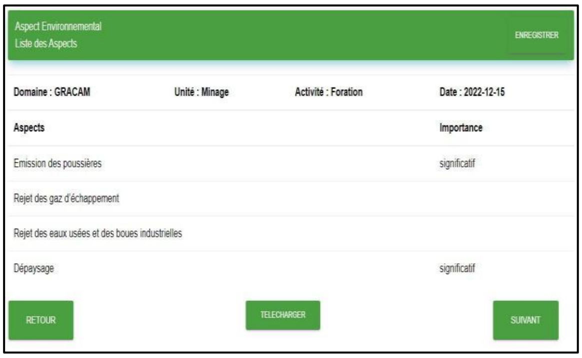

Figure 14. Screenshot of the interface to identify significant environmental aspects

Environmental risks assessment interface

In Figure 15 representing the risk assessment interface, the user has the possibility of characterizing the environmental risks previously identified using an assessment grid including elements such as frequency; severity; sensitivity; level of control so that criticality is calculated automatically.

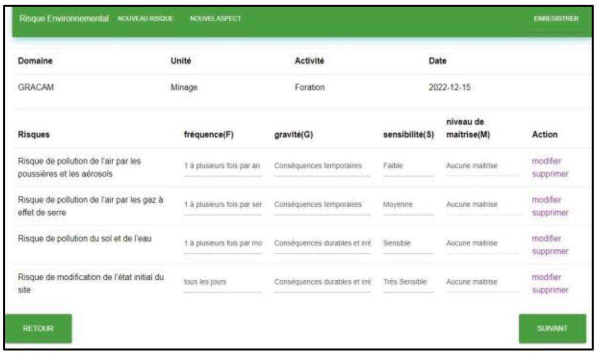

Figure 15. Screenshot of the environmental risks assessment interface

Interface of assessed environmental risks

Following the previous step, a table allowing the user to view the results of the risk assessment as well as preventive measures is proposed. Tabs such as "NEW RISK"; "NEW ASPECT" and "SAVE" allow the user to add new environmental risks and new environmental aspects specific to their structure to the assessment table. The "DOWNLOAD" functionality allows the user to save and print the results of the environmental risk assessment, as shown in Figure 16.

Figure 16. Screenshot of the assessed environmental risks interface

Environmental impact assessment interface

Figure 17 represents the environmental impact assessment interface, here the user can characterize the environmental impacts using Fecteau environmental impact assessment matrix including elements such as frequency; reversibility; intensity; scope; duration and probability of occurrence so that the absolute importance of the risk is calculated automatically.

Interface assessed environmental impacts

Following the previous step, a table allowing the user to view the results of the impact assessment is proposed. Tabs such as "NEW RISK"; "NEW IMPACT" and "SAVE" allow the user to add new environmental risks and new environmental impacts specific to their structure to the assessment table (Figure 18).

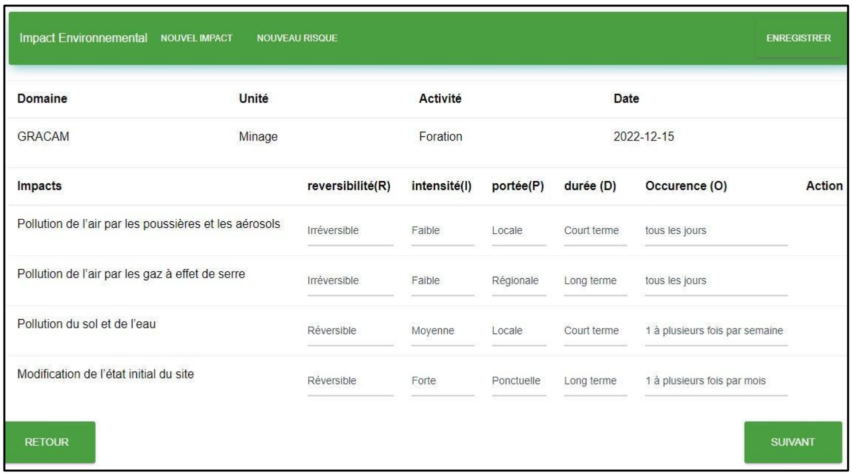

Figure 17. Screenshot of the environmental impacts assessment interface

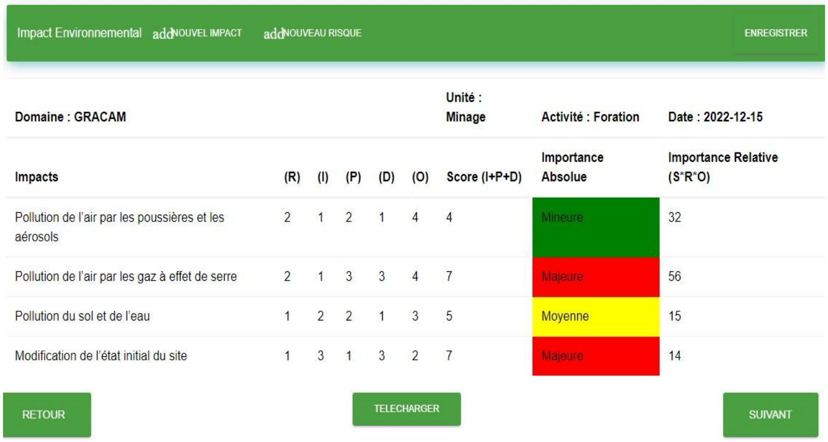

Figure 18. Screenshot of the assessed environmental impacts interface

Interface for ESMP development

In Figure 19, which illustrates the ESMP interface, the user can use it to develop an environmental and social management plan based on a series of questions that he or she must answer. Following the previous step, a table is presented to the user allowing him or her to view the results of his or her ESMP. The "DOWNLOAD" functionality allows the user to save and print the results of his or her ESMP.

Figure 19. Screenshot of the ESMP development interface

DISCUSSION

Throughout the world, and in Cameroon in particular, many legislative texts govern environmental protection. Regulatory pressures remain the main reason for taking environmental considerations into account. The same observation has also been made by other studies such as that of (Henriques & Sadorski, 1999). This study conducted by 400 companies concluded that companies in general are subject to various pressures regarding environmental issues and that regulatory pressure remains the most motivating in most cases. This situation could be explained by the fact that "the environmental issue is perceived as a constraint rather than an opportunity". (Nzambimana et al., 2021). In current case study, 15 risks were assessed for 13 aspects and only 1 is acceptable and the other 14 require urgent action, which makes a percentage of more than 93% (detailed information on the identified risks is not provided because the company did not give consent). This results in the absence of an environmental management plan. The absence of a real environmental management plan would be one of the components responsible for 78.6% of this major and average importance of the 15 impacts assessed. Studies on the issue are clear, the success of an EMS requires the commitment of senior management (Marquet-Pondeville, 2011). This designed software will first allow for an analysis of environmental risks and impacts and evaluate them efficiently and quickly. Then, to deploy an appropriate action plan. The environmental analysis software PREVISOFT, designed in 2013 by François Durieux, also allows you to carry out the same actions, but requires an internet connection and is not free, as are EcoOnline and ProcessMap. The EPESME software, designed in 2015 by Hariz, allows you to evaluate only the environmental performance of a company. It updates contribution of different indicators (air; soil; waste and energy) to assess environmental performance. However, with these software programs, you need an internet connection, you work only online, making them expensive, while GRIENV disk does not need a connection, you work locally, and it is even free. In general, GRIENV and PREVISOFT, EPESME software programs provide information that is easily and quickly usable. This situation helps reduce the time taken to analyse results and make adequate information available.

CONCLUSION

To summarize, the current research project achieved its goal by developing and validating a new computerized tool, GRIENV, to support companies in environmental management. Specifically, it provides software for self-assessment of environmental risks and impacts based on empirical methods, with the goal of improving their environmental performance. Testing the developed GRIENV software application allowed for an assessment of workplace risks and the identification of 15 risks across 13 aspects. Only one of these was deemed acceptable, while the remaining 14 required urgent action, representing a percentage of over 93%. It should be emphasized that these results were obtained in just a few hours, compared to the several days required with manual application. GRIENV is an effective solution because it delivers adequate results within an optimal timeframe.

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Author's statements

Contributions

Conceptualization: N.L.N.O.; Data curation: N.L.N.O.; Formal Analysis: N.L.N.O.; Investigation: N.L.N.O.; Methodology: N.L.N.O.; Project administration: N.L.N.O.; Resources: N.L.N.O.; Software: N.L.N.O.; Supervision: A.M., R.T.G.; Validation: A.M.; Visualization: N.L.N.O.; Writing – original draft: N.L.N.O.; Writing – review & editing: N.L.N.O.

Declaration of conflicting interest

The authors declare no competing interests.

Financial interests

The authors declare they have no financial interests.

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Data availability statement

Not applicable.

AI Disclosure

The authors declare that generative AI was not used to assist in writing this manuscript.

Ethical approval declarations

Not applicable.

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