Risk Assessment of Industrial Waste: *Case of an Algerian Company*

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ABSTRACT More than 300,000 tons of industrial hazardous wastes are produced every year in Algeria. Industrial waste can cause harm to people or the environment. The study highlights the problem of a very important step of the industrial waste management which is the storage. The Algerian regulation does not specify the storage mode of the different industrial wastes. This can cause very dangerous accidents such as fires and explosions. The main research technique is modeling according to a risk analysis tool. Using our assessment method (Preliminary Hazard Analysis), various risk factors can be classified according to their contribution to environmental and human health risks. The goal of this study was to study the risks associated with storing industrial waste and to assist businesses in improving their waste management practices for the purpose of sustainable development. The initial analysis of dangers and the Risk Assessment Matrix show that hazardous wastes like used batteries, used oils, and Askarel transformers can cause serious harm to the environment and humans if not handled safely. They can make the air, water, and soil dirty, and they can also contaminate the fauna and flora. **KEYWORDS** industrial waste, waste storage, risk assessment, preliminary hazard analysis method, environmental and human health risk, Algerian company

INTRODUCTION

Production and management of industrial waste is an important issue for the Industrial sector in developing countries (Sellitto, 2018). Chaudhary and Vrat (2018) said that developing countries are not as good as developed countries at managing industrial waste. One reason is that they don't have good ways to work together with others and collect and process waste. So, it is important to have a plan for dealing with the limited resources, the growing amount of waste produced by businesses, and the dangers it can pose to our health (Jabbour et al., 2017). The National Company of Wells Works (NCWW) is a company that belongs completely to Holding SONATRACH. NCWW generates hazardous waste, which is a severe liability and a cause of many environmental disasters (Xu et al., 2019). Improperly identified and managed hazard waste can damage human health and the environment (Duan et al., 2008). Hazardous waste is made up of dangerous solid or liquid waste that can be corrosive, toxic, flammable, reactive, or infectious (Trivedi et al., 2015). Ill-defined policies comprising prevention, disposal, and handling may lead to environmental degradation and pose severe public health risks (Hoveidi et al., 2013; Kimani, 2010). Risk assessment methods give us information about different situations. For example, they can help us decide on the best way to control pollution at a factory, predict the best options for managing waste, come up with different plans for managing waste, or find out if there are any risks that we need further attention (Environment Protection Authority [EPA], 2002).

Risk assessment is an inherent part of risk management that analyses the risk in terms of consequences and their probabilities before deciding if any further treatment is necessary (Manuele, 2016). Therefore, this article aims to assess the industrial risk of an Algerian company in the oil industry.

Thus, the main study technique is qualitative modeling according to a risk analysis tool. Similar studies in developing economies are useful to position our article.

Nevertheless, no information is available on the risk assessment of industrial waste storage, which is an important step for any industrial waste management system. Storage can take a long time in company and may or may not comply with occupational health and safety regulations. Therefore, there is a need to study the risk of

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industrial waste storage and its effects on the health of workers, the company, and its environment. It is the novelty embedded in our study. The main objectives of this work are (1) to find out how the handling and storage of the waste produced by NCWW can affect human health and the environment and (2) to demonstrate how the findings of this study can help decision-makers implement a sustainable management system to lessen the risk associated with industrial waste.

ALGERIAN LEGISLATION IN THE AREA OF SOLID WASTE MANAGEMENT

Countries created laws to address the issue of industrial waste, but sometimes, it's difficult to enforce these laws. Effective waste management is important to prevent problems and ensure stability. This can be done by clearly defining the roles and responsibilities of institutions and government bodies. This helps to avoid arguments, inefficiency, and lack of action. It also helps to keep waste management systems stable and away from political issues (Schübeler, 1996). In Algeria, the most important law is Law Number 01–19. The text is talking about rules for managing and getting rid of waste. These rules explain the main ideas for handling waste, from how it is made to how it is thrown away. In Algeria, programs for handling dangerous waste have achieved success by making the generator responsible for correctly categorizing industrial waste. The generator's job is to control and manage dangerous waste from the time it is made until it is thrown away. Generators of hazardous waste can face big punishments if they don't make sure their hazardous waste is handled the right way.

Algerian environmental legislation requires proper management and treatment of industrial waste to avoid possible environmental degradation. The main texts are listed as follows:

- Executive Decree No. 02-372. The text is about the law on packaging waste that was passed on November 11, 2002.
- A rule made by the government. On December 9, 2003, the ways and steps for creating, sharing, and updating the national plan for handling dangerous waste were established in document 03-477.
- Executive Decree No. 04-409, issued on December 14, 2004, lays out the rules and procedures for transporting dangerous special wastes.
- Executive Decree No. 03-478. On December 9, 2003, law 03-478 was created to explain how health care waste should be managed.
- On December 14, 2004, a law called 04-410 was made to create rules for waste treatment facilities. The law also specifies the conditions that waste needs to meet in order to be accepted by these facilities.
- On February 28, 2006, document 06-104 was released. This document updates the list of waste, including hazardous waste.
- Executive Decree No. 09-19 of January 20, 2009 sets rules for the collection of special waste.
- Executive Decree 05-315, issued on September 10, 2005, outlines the steps for reporting dangerous waste that requires special treatment.
- Executive Decree No. 87-182. This law from July 18, 1987, is about oils, equipment, and materials that contain a harmful chemical called polychlorinated biphenyl (PCB).
- The text of September 2, 2013, sets out the specific details of labels for dangerous waste.

METHODOLOGY

Risk refers to situations or circumstances that can be dangerous or harmful to people or the environment. Risk assessment is about looking at how likely something bad might happen and severity of a specific risk incident (Zhongguang et al., 2020). This study wants to understand the dangers of industrial waste and how it can affect people's health and the environment. It also wants to know which types of waste are the riskiest and need to be handled carefully and managed correctly. According to Aivaliot (2014), poor handling and getting rid of industrial waste has caused big problems for the environment, especially in developing countries. It has led to issues like dirty air, contaminated water, and polluted soil. Also, it was found that if industrial solid waste is not disposed of properly, it can cause dirty and unhealthy conditions. This can lead to the spread of diseases carried by insects and rodents (Awuchi et al., 2020b). This research uses a method called Preliminary Hazard Analysis (PHA) to find and assess dangers and risks related to storing industrial waste. PHA is a good way to evaluate possible dangers (Yan & Xu, 2019). This is a type of analysis that gives an approximate

TABLE 1. Risk Assessment Matrix.

Risk Matrix (R)					
	Likelihood (L)				
Severity (S)	1 Rare	2 Unlikely	3 Possible	4 Likely	5 Almost Certain
1 Insignificant	Low 1	Low 2	Low 3	Medium 4	Medium 5
2 Minor	Low 2	Medium 4	Medium 6	High 8	High 10
3 Moderate	Low 3	Medium 6	High 9	Extreme 12	Extreme 15
4 Major	Medium 4	High 8	Extreme 12	Extreme 16	Extreme 20
5 Catastrophic	Medium 5	High 10	Extreme 15	Extreme 20	Extreme 25

Note: Colors of risk intensity—green for low risk, yellow for medium risk, orange for high risk, and red for extreme risk.

measurement, and it is done by following certain steps (Rausand, 2004):

- Find and recognize anything that could cause harm or lead to an unintended event that could result in an accident.
- Arrange the accidental events based on how bad they are.
- Find and use the necessary ways to prevent accidents or dangers, and carry out further actions as needed.

Next, in order to determine how likely something is to happen, we utilized the risk assessment matrix developed by Rausand in 2004, which is displayed in table 1.

To figure out possible risks for waste storage, we look at lots of information and data from different sources. At a location, we assess things by inspecting them and analyzing the results. We also look at reports about important accidents and incidents that happened in the last 10 years. We also consider official documents about waste. Additionally, scientific papers about how to control and reduce hazards associated with storing industrial waste. The diagram in figure 1 shows how the work is organized.

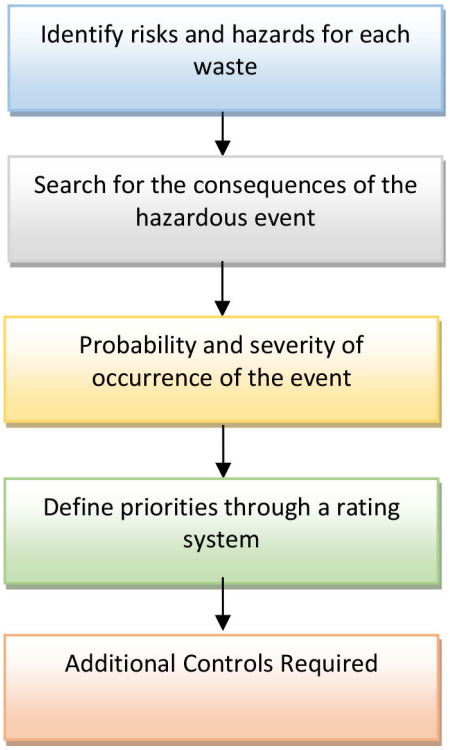

FIGURE 1. Structure of the work.

CURRENT INDUSTRIAL SOLID WASTE MANAGEMENT IN NCWW

NCWW is a wholly owned subsidiary of Holding SONATRACH (Sonatrach is the 12th largest oil consortium in the world). NCWW is a great company, in charge of the execution of research and development drilling on liquid and gaseous hydrocarbon deposits and the maintenance of oil and gas producing wells (workover) and, incidentally, deep hydraulic drilling. Its head

TABLE 2. Quantities of the National Company of Wells Works (NCWW) Wastes in 2019.

Waste Type	Household Wastes	Nonhazardous Wastes	Hazardous Waste	Health Care Waste
Quantities (kg)	878,312	537,304	409,747	86,755

Source: Authors.

office is located in Hassi Messaoud, City of Ouargla, south of Algiers, about 900 km away. Activities of NCWW are:

- Drilling and work over activities (maintenance of water gas oil-producing wells);
- Transportation (rigs and drill camps, delivery of equipment and consumables, maintenance of the company's vehicles and machinery, and the transport of personnel);
- Petroleum maintenance (the renovation of equipment and drilling camps, the manufacture and reconditioning of refill parts, and interventions on-site for the prevention and safety at the wells).
  Hotels and catering (provide accommodation and catering services to the personnel).

Solid wastes generated by NCWW are related to drilling activities which can be nonhazardous (used tires, wood, plastics, and scrap metal), hazardous (Freon bottles, compressors, aerosol cans, and ink cartridges, used oils, used batteries, asbestos wastes, and Askarel transformers, health care waste, chemical waste), inert waste, and household wastes. During our work experience at the company in March 2019, we figured out how much waste was produced based on the waste management report (table 2).

Household waste constitutes the largest quantity. Furthermore, nonhazardous waste and hazardous waste remain significant. Current management techniques of these wastes in NCWW deal with:

- Identification of waste according to its nature;
- Sorting and storage conditions for each type of waste;
- Removal and treatment are reserved for each type of waste produced.

So, all the wastes generated by NCWW, when improperly stored, transported, or managed pose a significant present or potential hazard to human health or the environment. Therefore, all waste produced by NCWW poses serious current or potential hazards to human health or the environment if improperly stored, transported, or handled. Thus, we considered this company is the best to answer the research question.

RESULTS AND DISCUSSION

After gathering information, we used the PHA to study the industrial waste produced by NCWW (as shown in table 3).

The PHA applied to the waste generated by the NCWW, allowed us to assess the risks, consequences of these risks, and their severity. Risks for the different wastes are: Household wastes produced by Catering are putrescible, glass, sanitary textiles, aluminum packaging, the risk is medium (6) because the severity is minor (2) and the likelihood is possible (3). If the exposure time is extended, they can present risks, such as the proliferation of vermin, infiltration of leachate, loaded with toxic particles on the ground aided by rainwater that reaches the water tables and pollutes them. Therefore, to avoid these risks actions are required. However, by separating waste at its origin, recyclable and biodegradable materials can be collected and turned into useful products (Foolmauna et al., 2011). This means taking recyclable items and turning them into usable materials, energy, or resources. The last treatment method for this type of waste is landfilling or incineration without energy recovery. Nonhazardous waste represents a medium risk. Risks are fire, injuries, and pollution. These wastes, such as used tires, wood waste, and metal waste, are composed of a single type of material that makes it easier to recycle. According to Saidan (2019), many types of industrial waste that are not harmful can be recycled and sold for a good price in the recycling market. However, when it comes to items that cannot be recycled or are very difficult to recycle, the energy obtained from these wastes is considered as part of the waste management plan (Awuchi et al., 2020a).

Hazardous waste represents the highest risk. These wastes can present an extreme risk (12) as their severity is considered major (4). Hazardous waste includes used batteries, used oils, Askarel transformers, and waste containing asbestos. These different types of waste can cause big problems for the environment and people's health. They can pollute the soil, contaminate the water underground, harm plants and animals, cause fires and explosions, and make people sick with irritation, harmfulness, or toxicity.

TABLE 3. Preliminary Hazard Analysis Applied for Industrial Waste of the National Company of Wells Works (NCWW) Company.

Waste	Risks	Consequences	Criticity S	L	R	Additional Controls Required
Household wastes: - Putrescible waste, foodstuffs - Glass - Sanitary textiles, soiled paper fraction - Aluminum packaging	- Decomposition of organic matter present in the waste piled up in the bins-Emanation of putrid and nauseating odors (CH_4) due to the fermentation of the waste - Emissions of toxic gases (biogas) such as methane and carbon dioxide from odors - Leachate loaded with toxic particles - Proliferation of various vermin insects, field mice, and stray animals - Risk of cut	- Respiratory diseases: asthma, rhinitis . . . - Provokes several diseases: conjunctiva, allergic diseases - Proliferation of vermin - Infiltration of leachate loaded with toxic particles on the ground aided by rainwater that reaches the water tables and pollutes them - Dispersion of discharges loaded with microorganisms on the ground, aided by the rainwater that reaches the water table and pollutes it - Transmit infectious diseases/ gastroenteritis/diarrheatry to avoid . . . - Drowning and death - Deterioration of the landscape - Injuries	2	3	6	- Staff awareness (Job Safety Analysis [JSA], Tool Box Talk [TBT], and Tool Box Meeting [TBM]) - Optimize the waste management plan - Maximize the percentages of recyclable materials sent for recycling - Prevent the long-term accumulation of waste on the site
Nonhazardous waste: - Used tires - Wood waste - Metal waste - Carton drilling tool	- Fire - Injury when handling wood (splinters, staple, and nail bites) - Pollution with the powder contained in the ink cartridges - Cuts when handling metal waste	- Pollution and release of toxic black fumes - Fire spread to another nearby facility - Injuries and trauma - Deterioration of the landscape	3	2	6	- Provide for regular removal to avoid excessive build-up -Regulated storage - Providing for the reuse and recycling of materials
Hazardous waste: - Used batteries - Used gear oils - Rigs Generator Group, Askarel transformers	- Infiltration of used oils and lubricants - Leakage of fuels and oils from machinery - Risk of toxicity to fauna and flora - Risk of explosion/fire	- Soil pollution - Groundwater contamination - Contamination of fauna and flora - Health effects by-product: Irritation, harmfulness, toxicity, dermatologic,	4	3	12	- Staff awareness (JSA, TBT, and TBM) - Regular maintenance of construction machines and generators - Monitoring of energy consumption

(continued)

TABLE 3. *(continued)*

Waste	Risks	Consequences	Criticity S	L	R	Additional Controls Required
(polychlorinated biphenyls) - Asbestos waste (brake pad) - Flammable liquids used as diluents (petroleum, white spirit, acetone, toluene)		hepatic, carcinogenic, cardiovascular, gastrointestinal, asbestosis, and lung cancer - Landscape degradation				- Implementation of a spill contingency plan to limit the spread of the spill and facilitate crisis management
Inert and bulky wastes: - Landslide, rubble, rocks - Plastic material: casing protector, barrels ... - Packaging: wooden big bag cases and mud product drums	- Ingestion of plastic and cardboard by animals - Reuse of barrels by residents for drinking water storage	- Potential soil contamination - Contamination of people when reusing discarded drums - Deterioration of the landscape	2	2	4	- Daily sensitization of the staff (toolbox talk, JSA...) - Segregation and recovery of inert waste (plastic, wood, cardboard ...) by the drilling contractor and transfer to authorized landfills following the regulations in force with a follow-up sheet - Rehabilitation of drilling sites
Sludge	- Infiltration, overflow, toxicity - Decomposition of additives used - Inhalation of vapors from decomposing products - Emanations of bad smells - Spill of polluted water (water, powder, foam, chemicals) - Discharge of hot fluids - Drop of people and livestock into the quagmire	- Potential soil contamination - Potential groundwater contamination - Contamination of animal species - Health effect byproduct: irritation, harmfulness, toxicity. - Olfactory gene - Carcinogenic effects - burn - Reduced biodiversity - Landscape degradation	3	3	9	- Adequate management of these liquid discharges strongly limits potential contamination of soil, groundwater, and wildlife, as well as risks to employees - The implementation of appropriate monitoring of good conditions prevents and reduces the risk of leaks - Strict monitoring of drilling procedures and mud programs - Recovery of mud at the end of each drilling operation for reuse in the next well to be drilled

(continued)

TABLE 3. *(continued)*

Waste	Risks	Consequences	Criticity S	L	R	Additional Controls Required
Health care waste: - Drugs, disinfectants products, gloves - Sharps waste	- Direct contact with microorganisms - Risk of cut, scrape	- Contraction of infectious diseases - Potential soil contamination - Contamination of fauna and flora - Landscape degradation	4	2	8	- Staff awareness (JSA, TBT, and TBM) - Management of health care waste by the contractor by the regulations in force with a follow-up sheet

Note: S = Severity; R = Risk matrix; L = Likelihood.

Batteries are considered dangerous waste and are commonly seen as dangerous waste from factories, businesses, and homes (Winslow et al., 2018). So, old batteries are taken back and sent to companies that recycle or dispose of them. It's better to recycle and reuse used oil instead of operation for use in the upcoming well. This can help our environment a lot. You can take old oil and turn it into new oil, use it as fuel, or use it to make other things. The biggest sources of PCBs are waste transformers and Askarel transformers. PCBs are harmful substances that can cause many different health problems. These problems can affect the skin, reproductive system, development, hormones, liver, cancer risk, heart, digestion, immune system, muscles, and brain (Saeedi et al., 2017).

Askarel transformers should be kept in a storage area made of a material that doesn't allow PCBs to pass through, like steel. The storage place should be checked once a month to make sure that equipment and waste materials contaminated with PCBs are stored correctly, so that no leaks happen. It is also suggested to get rid of old equipment that has PCBs (EPA, 2008). Asbestos, a dangerous material found in waste, can enter our bodies when we breathe it in or come into contact with its fibers. This can lead to serious health issues like mesothelioma, asbestosis, and lung cancer (EPA, 2017). Currently, the only approved way to get rid of waste containing asbestos is to put it in special places for dangerous waste or in specific areas of other landfills (Szymańska & Lewandowska, 2019).

Inert and bulky wastes are like a landslide, rubble, barrels in plastic material, packaging with large wooden bag cases, and mud product drums. The risk of these wastes is medium. Potential soil contamination and deterioration of the landscape are essential risks. The treatment for the majority of this waste is to be reused. There is a higher potential for value recovery by reusing pallets and packaging (Sellito, 2018), or recycling and, at worst, landfill.

Sludge is considered a hazardous waste with a high risk (9). Potential soil contamination, potential groundwater contamination, health effect by-product: irritation, harmfulness, olfactory gene. So, several treatments can be utilized as incineration, anaerobic digestion, and sanitary landfill (Haque, 2020). According to Chen et al. (2020), a process called sludge digestate pyrolysis was used to reduce the chances of harming the environment. It also helped to save energy, collect useful materials, and create valuable products.

Another waste category with a high-risk profile is health care waste. Health care waste mainly consists of medicines, cleaning agents, and sharp objects. Sharp objects can cause cuts and holes in the skin and if they have harmful germs on them, they can make the wounds infected. Due to the increased chance of getting hurt and spreading diseases, sharps are considered a highly dangerous type of waste (Sefouhi et al., 2013). The risk of accidental contact with blood and body fluids will be increased in different situations, especially during health care waste's handling and transportation (Sefouhi et al., 2020). Then, awareness of correct handling and disposal of health care wastes among health personnel is a priority; everybody should know the potential health hazards (Patil & Shekdar, 2001). However, health care facilities require instruments and equipment to make the handling of dangerous health care waste safer and more suitable

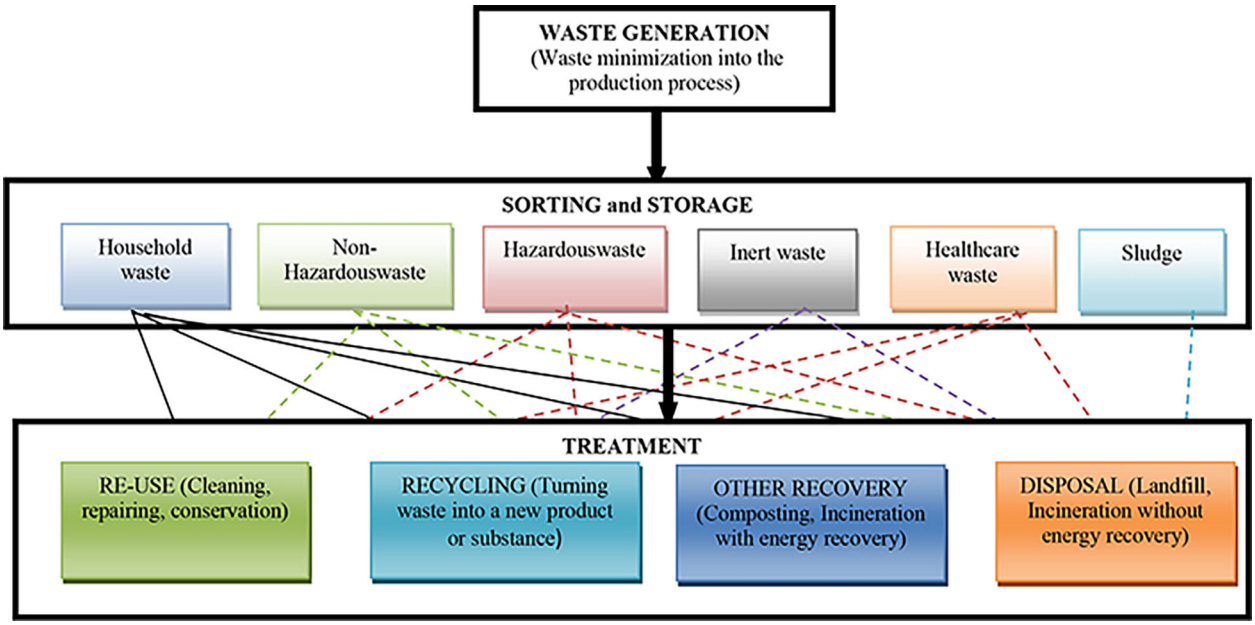

FIGURE 2. Integrated solid industrial waste management in the National Company of Wells Works (NCWW) Company.

(Carvalho & Silva, 2002). A study of Ansari et al. (2019) discovered that improper disposal of waste from hospitals has led to environmental risks in many developing countries. The study reviewed previous research to reach this conclusion. Health care waste should be subjected to disinfection and mutilation before reuse, recycling, or disposal (Patil & Shekdar, 2001).

We had the privilege of examining the risks linked to the storage of waste produced by NCWW. Most of these wastes will be thrown away in designated areas called landfills. According to Ahmad et al. (2020), every year, billions of tons of petroleum and coal are taken out of the ground to make things. These things either get thrown into big piles of garbage or end up in nature, like on land or in water. They can also get burned and spread pollution into the air. So, in order to make things safer and create less trash in landfills, we need a new plan for handling solid industrial waste at NCWW that is sustainable. Sellitto and Almeida (2019) revealed that in developing countries, when manufacturing companies implement measures to reduce their negative impact on the environment, it can also have additional benefits like lowering costs, improving product quality, or enhancing reliability. We have a plan to manage all the different types of waste that the NCWW Company produces (figure 2).

The NCWW Company can look at how it manages waste. This can help to make less waste, and they can then recycle and reuse wastes. According to Zhang et al. (2018), recycling industrial waste helps companies collect and use their leftover materials again in their production process. We can save money by using recycled waste instead of buying new materials. The final option for getting rid of this waste may be putting it in a landfill. We have a plan that was created based on the goals set by Kirkpatrick in 1992. The overall strategy of waste management will ensure that we follow a specific order to reduce waste, reuse items, recycle materials, burn waste, and dispose of it properly.

CONCLUSION

Wastes generated by NCWW are mainly household waste and also nonhazardous and hazardous wastes. Their management system has some deficiencies. Our research found that NCWW waste management is risky and can harm people and the environment.

This study aimed to show the negative impacts of storing industrial waste from NCWW. Some types of dangerous waste, like used batteries, used oils, Askarel transformers, and Asbestos waste, can stay in our environment for a long time. Health problems that can happen include cancer, hepatitis, and skin irritations.

Risks are relatively significant concerning waste from drilling, civil engineering work in the management of living bases. We have noticed that nonhazardous and hazardous waste is stored in storage areas for removal by a subcontractor. Subsequently, the fate of these wastes

is unknown. Thus, control measures have been taken to minimize risks and be in compliance with Algerian legislation.

Notwithstanding, segregation of solid waste was observed. However, recycling is still ill practiced. Possibly this comes back to the shortcomings, which have been noted in the regulatory texts concerning the interest of recycling and energy recovery of hazardous industrial waste. Concerning the hazardous wastes, the Algerian law prescribes the name of the waste, the code of the waste, its physical state, its chemical composition, its criterion of dangerousness. On the other hand for the storage of the hazardous wastes, the law does not foresee the type of storage and the modalities of management or control or elimination. Also the Algerian regulations are devoid of measures to avoid the production of hazardous waste or management measures such as reuse, recycling, recovery, or disposal. To decrease the amount of waste that gets thrown away, it's important to encourage recycling and reusing. The Algerian environment authorities need to create rules and regulations that control how different types of waste from production should be handled, based on the materials and processes involved. For instance, when it comes to waste oils, there is a focus on the process of refining them.

Based on this research, it is proposed to adopt texts that require varying levels of supervision regarding retrieval or disposal, depending on the criticity shown in table 3. These fall into one of the following categories:

- Nonsupervisory waste refers to waste that is similar to household waste, like paper, cardboard, wood, glass, plastics, metals, and so on.
- Waste requiring monitoring (used tires or sludge from company effluent treatment facilities).
- Special monitoring is needed for certain types of waste. This includes waste paints and varnishes that have chemicals called halogenated solvents, batteries called accumulators, fluids used in brakes, paints, glues, chemicals used in photography, lubricants, and machinery oils that have chlorine in them.

The company needs to tell the authority in charge in its area about the type, amount, and makeup of the waste they have, as well as their plan for getting rid of it. The text doesn't indicate that the company has to do this. The authority chooses the right place to treat this waste before it is disposed of. Extra or leftover materials are thrown away in a landfill.

Finally, our work can help the company's decision-makers make better decisions about how to store and manage waste. Moreover, Algerian regulators can use the information from this case study to create a law that informs and educates workers about the risks of hazardous industrial waste. The new plan for handling waste is meant to make sure that waste doesn't harm people or the environment as much. This means reducing waste and managing it better by putting more effort into recycling. More studies should be done to understand how much it costs to store industrial wastes and manage them properly.

CASE STUDY QUESTIONS

1. What happens to people and the environment when waste is not handled, stored, transported, or thrown away properly?
2. Which wastes represent the highest risk and deserve special attention?
3. Are the personnel in charge of collecting and storing the waste informed of the risk involved? And are they sufficiently protected?
4. How do an analysis of risk in terms of consequences and their probabilities affect management system of waste?

AUTHOR CONTRIBUTIONS

Contributed to investigation, data curation and methodology, software, and writing: LS.

Contributed to supervision and review: LB.

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COMPETING INTERESTS

The authors have declared that no competing interests.

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