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Evaluation of Industrial Waste in the Paints Industry Sector: Khartoum North Industrial Area,

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Abstract: The study focused on the management of industrial waste in the paints industry in the Khartoum North industrial area. The research material was collected through laboratory analysis of wastewater samples resulting from factories and subsequently compared with the instructions of the Sudanese standard board for wastewater.

Through measuring the concentration of suspended microparticles in the production units and comparing them with occupational health instructions in addition to direct observation and a questionnaire-based exercise for factory departments.

The results showed that the wastewater was discharged into the sewage network without adhering to the standards of the Sudanese standards board. Solid waste was disposed of in a landfill without treating of the hazardous waste, also factories do not treat the polluted air by the suspended particles.

The paper recommended that there is a need to implement integrated environmental management of Sudan's industry and keep pace with the global development in the field for combating industrial pollution from its sources and to encourage further research and studies in this area.

Keywords: Paints Industry - Industrial Waste Management - Wastewater - Suspended Particles - Sudanese Specification

تقييم النفايات الصناعية في قطاع صناعة الدهانات - بمنطقة الخرطوم بحري الصناعية

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المستخلص: ركزت الدراسة على إدارة المخلفات الصناعية بقطاع صناعة الدهانات بمنطقة الخرطوم بحري الصناعية ، جمعت المادة البحثية عبر التحليل المعملي لعينات المياه العادمة الناتجة عن المصانع ومقارنتها بتعليمات المواصفة السودانية للمياه العادمة - قياس تركيز الجسيمات الدقيقة العالقة في وحدات الإنتاج ومقارنتها بتعليمات الصحة المهنية بالإضافة الى الملاحظة المباشرة هذا الى جانب استبانة لإدارات المصانع ، أظهرت النتائج أنا المصانع تصرف المياه العادمة في شبكة الصرف الصحي دون الالتزام بتعليمات المواصفة القياسية السودانية و يتخلص من المخلفات الصلبة في مكب النفايات دون معالجة الخطرة منها كما أن المصانع لا تعالج الهواء الملوث بالجسيمات الدقيقة العالقة، توصي الورقة – ضمن توصيات أخرى – بضرورة تطبيق الإدارة البيئية المتكاملة للصناعة وموا كبة المصانع للتطورات العالمية في مجال مكافحة التلوث الصناعي من منابعه وتشجيع البحوث والدراسات في هذا المجال .

الكلمات المفتاحية: صناعة الدهانات - إدارة المخلفات الصناعية – المياه العادمة - الجسيمات الدقيقة العالقة – المواصفة السودانية.

Introduction

The most important thing facing our world today is the environmental pollution that comes from industrial waste, whether liquid, solid or gaseous. As the industrial development that we are witnessing today has not been kept up with, to the same extent, in the development of industrial waste management, which is the methods of transportation, collection and final disposal of the waste produced by the industry.

In all stages of production, it is environmentally safe as well as an economically inexpensive method, this means that the industrial waste management system is related to controlling the production, storage, collection, transport, movement, treatment and final disposal of waste within the framework of the best principles of health, economics and acceptable environmental frameworks. Especially since industrial waste management is closely linked with issues of urbanization and sustainable development, as well as improving professional ethics and public health and reducing resource waste.

The characteristics of pollutants present in industrial waste, especially liquid ones, differ from one industrial sector to another. So, it is difficult to give general specifications for them, but industrial wastewater can be defined as liquid products that are present during water use in various processes involving raw materials and converting them into industrial products. And by using it in the stages of manufacturing goods or consumables, water used for cooling, washing, boilers and chemical conversion [(1)]. The products that are used which have economic feasibility are not wastewater.

As for solid industrial waste, it is intended for all the waste resulting from industrial processes and cannot be used either for re-use, recycling or selling [(2)]. Therefore, solid by-products that are used and have economic feasibility are not included in industrial waste. Industrial gaseous waste includes all the pollutants that the industry releases (liquids, solids, and gases) into the air in varying proportions and concentrations that may cause harm to humans, animals, plants, and inanimate objects, therefore, industrial gaseous waste include gases and suspended particles in addition to sprays.

The effects and damages that industrial waste inflicts on the environment and human health depends on the properties of the waste and the elements they contain. Some industrial waste is hazardous with physical, chemical or biological characteristics that require special conditions for their collection, transport and treatment in order to protect public health and safety [(3)].

The dangerous industrial sector includes all the by-products of the industry (gases, liquids, and solids) that have properties that negatively affect human health and environmental systems in the absence of conditions for transporting and treating this waste. These conditions, guarantee human health and environmental safety, especially since there is a lack of clear plans or standards to deal with the waste and the resulting environmental pollution.

This leads to the loss of opportunities to employ them as resources that can be used [(4)] therefore, the matter of treating and disposing of the waste in an environmentally safe manner requires clear and thoughtful planning. This can be represented in the application of integrated environmental management for the industry, which is concerned with developing environmental plans and policies to monitor, follow up and evaluate the environmental impacts of the plant. This includes all production stages starting from obtaining raw materials to the final product and the environmental aspects related to it.

Environmental management includes the functional structure of the plant in addition to planning, responsibilities, operational practices, possibilities for development, implementation, review, and follow-up of the environmental policy with the aim of reducing negative environmental impacts and trying to prevent them [(5)]. Adherence to the industry's integrated environmental management method achieves the protection of the environment and the health of the worker as well as the economic gains.

The principles and objectives of this method and its support for cleaner production, prevents the generation of industrial waste and the maximum use of it by re-use, recycling or selling methods, especially since the integrated environmental management plan includes the collection, transportation, and treatment of industrial waste in an environmentally safe manner, that achieves environmental quality as well as being economically inexpensive.

The principle of recycling is considered one of the most important principles of environmental management of industrial waste. The process of recycling waste is intended to convert it from a product polluting the environment to a product with an economic return. This achieves savings in the economic cost of manufacturing products, as well as reducing the cost of processing the waste resulting from these products [(6)]. As for the waste that cannot be used, it is treated and finally disposed of within the environmental management of industrial waste. This includes the final treatment of industrial waste according to environmental standards and controls, adherence to laws and legislation, and its application of environmental quality standards [(7).]

Among the environmentally safe treatment methods for solid waste is the method of safe burning and the method of sanitary landfill, where the former leads to the reduction of solid waste by 90%, as well as converting the latent heat in the waste into thermal energy to ensure the protection of the environment from any emissions. Here incinerators were designed according to special technical controls [8].

The sanitary landfill method is used to bury the waste and ash resulting from the safe burning process, so it is a complementary method to the safe burning method. This method depends on a technical and health criterion represented in the selection of the landfill site and its design, in addition to hydrological conditions and properties [9]. It's important also to understand the chemical and biological properties of the waste, especially the amount and weight of the waste and an estimation of its hazardous materials.

One of the duties in the environmental management of liquid waste is to limit the generation of waste and make use of it, by reducing water consumption and by recycling the resulting polluted water and re-gaining the materials usable from the polluted water at the site of its formation and destruction in their various stages. So, the aim of this is to control the negative environmental effects resulting from the drainage of this water into waterbodies or valleys, and to make it suitable for use in irrigation and other industrial purposes. A suitable quality can also go into the public sewage networks [10].

The drainage method within the sewage network is one of the main ways that factories use to dispose of industrial wastewater. The factories use the network according to environmental specifications and requirements for the quality of the water that is discharged.

One of the focus areas for cleaner production in industry is the prevention or limitation of gas emissions by controlling pollution inputs and treating the problem before its occurrence. Also, in using cleaner energy sources and using appropriate technology technically and economically, for example to suspend materials through using electric filters.

The Khartoum North industrial area is one of the oldest and largest industrial areas in Sudan, it comprises of 548 factories distributed in eight major sectors. Each sector includes several sub-industrial sectors [11] . These factories lack statistics for counting the different types and quantities of waste, (except for liquid waste and its management). This includes solid waste that is burned or buried without classification of whether or not its hazardous waste is toxic or radioactive. For liquid waste, there are some primary treatments, but most factories throw their wastewater in the open water or in the sewage network, and there is no treatment of air pollution [12].

The chemical industries sector is the most prominent of the major sectors. This sector also includes many sub-industrial sectors, including the paints industry, which has witnessed a growth through large-scale development. This can be clearly seen in the number of factories and production lines. However, this sector is one of the industrial sectors that is shrouded in ambiguity, especially with regards to the large level of industrial waste they produce during the various stages in production of paints. The paints industry is also one of the industries that produces final industrial waste, some of which is very dangerous to human and environmental health.

The environmental pollution caused by the industry is due to the failure to manage the industrial waste produced by the industry during the various stages of production. Therefore, this paper seeks to shed light on the different types and characteristics of industrial waste produced by the paints industry sector, in addition to focusing on managing this waste.

Objectives of the study

The objectives of this research are outlined below:

1. To gain knowledge of the quality of wastewater generated by the paint factories and how to manage it.
2. To gain knowledge of the quality of solid waste resulting from the study sample and how to deal with it.
3. To determine the quality of air pollutants emitted because of industrial processes and how to deal with air pollution.
4. To evaluate the extent of the study factories' compliance with the Sudanese standard specifications for final disposal of industrial waste.
5. To conduct an evaluation of industrial waste management in the paints industry sector.
6. To draw attention to the failure in industrial waste management and to highlight the importance and benefit of the environmental management of industrial waste.

Data collection methods

In collecting the data, this paper relied on laboratory analysis of wastewater samples coming out from the study factories and measuring the concentration of fine suspended particles in the factories' work environment. In addition to this, a questionnaire was designed for study factories, to capture the different methods of industrial waste management and the departments responsible for it. This was supported by researcher observation during field visits to factories and direct engagement with these departments on how to deal with industrial waste, including methods of collecting it, treating it and disposing of it.

Study methodology

This paper provided for the study and evaluation of industrial waste management in the paints industry sector in the Khartoum North Industrial area, through the following tests and procedures:

Laboratory analysis

The laboratory analysis involved samples taken from the manhole entering the sewage network. The wastewater samples (resulting from the study factories) were transferred to the environmental laboratories for further analysis in order to determine the level of water pollution that could be evidenced by increased or decreased levels of concentrations, and the following properties:

- PH – this indicates the degree of alkalinity in water measured using the Electrode PH Meter Class.
- Total dissolved solids – these are the substances dissolved in industrial wastewater and can include a combination of Potassium, Calcium, and Magnesium salts. The increased concentration of these substances is an indicator of water pollution.
- The calcium and magnesium salts were determined by titration with EDTA solution and the use of EBT reagent.
- The potassium salts were determined using flame spectrometer, the results were calculated in mg/l.
- Total suspended matter – this refers to the substances present in wastewater in the form of insoluble substances.
- Chemical oxygen demand – this is dependent on whether organic matter can be oxidized in the presence of an acidic medium. This test is useful for estimating the amount of oxygen required for the oxidation process (of organic matter in the examined liquid).
- Biological oxygen demand – this is an indication of wastewater pollution with organic matter. If the amount of biological oxygen consumed is large, then the degree of organic pollution is high.
- Trace elements – these include Lead, Manganese, Copper, and Iron and can be read by atomic absorption.
- Sulfides.
- Oils and greases.

To assess the pollutant content of wastewater samples coming out of the study factories, the study results were compared with the measurements of the Sudanese Standard for Industrial Liquid Waste. The measurements used were for 'after treatment inside the factory, which is disbursed to the sewage network' as issued by the General Organization for Standardization and Metrology in 2008.

Measuring particle concentration

The concentrations of fine suspended particles in the working environment of the study factories were measured using the Personal Sampler Sunder Pt pump (model: Casila AFC24). This was done by hanging the device on a worker's chest for 1 hour, the filter is then weighed, and a filter weight value is recorded. The weight difference is then calculated, where the difference is the weight of the fine particles in milligrams, which is subsequently converted into a value of mg/m3 and compared to the occupational health instructions. Occupational health instructions set 10 $mg/m^{3)}$/ hour as a maximum exposure to suspended particulate matter, and exceeding this limit can lead to disease.

Factory samples

The number of factories in the paints industry found in the Khartoum North Industrial area amounted to 10 factories

(Investment and Industry Authority, Khartoum State, 2006). This study selected a sample of 30%. Therefore, resulting in a sample of 3 factories known as p/1, p/2, p/3 (the study used these labels to anonymize the data instead of factory names).

Questionnaire

A questionnaire had been provided to the factory administration in order to collect information on methods of industrial waste management. The questionnaire included six sections, the first section collates general information, and the second section collates information about the industry. The third section collates information about liquid waste, its quality, methods of treatment and final disposal. While the fourth section collates information about solid waste, its quality, properties, methods of treatment and final disposal. The fifth section collates information on air emissions from their sources and the methods of reducing or preventing them. Finally, the sixth section collates information on the environmental management of industrial waste, especially the monitoring and measurement of air and wastewater pollutants. A follow-up task for this section is the evaluation of adherence to standards adopted in Sudan.

Discussion

This study produced the following results in liquid waste management, solid waste management, air pollution management and overall environmental management.

Liquid waste management

It became evident from the fieldwork and data collection analysis that the liquid waste from the paint factories sample is the residue of production and the mixture of materials. It was also evident that in addition to washing water, the water contains oils, chemical dyes, ammonia, and calcium carbonate. Regarding liquid waste disposal, the field study revealed that there isn't a disposal system. Therefore, industrial wastewater is disposed of in the sewage network without any prior treatment. It is transported through the sewage network to the main station in the Wad Dfiia area. This study revealed that out of the sample of factories, all (100%) discharged wastewater without any prior treatment.

In order to know more about the quality and properties of wastewater resulting from the study sample and its contamination content. The results of its measurements were compared with the instructions of the Sudanese standard for industrial wastewater after treatment and before being discharged into the sewage network, as shown in Table (1).

Isotropic	PH	Total dissolved solid	Total suspended solid	Bio oxygen demand	Chemical oxygen demand	Oil and greases	Lead	Manganese	Iron	Copper	Sulfides
Standard instruction mg\liter	6.9	2500	400	350	250	20	0.1	0.1	2	2.5	2
Factory p\1	7.9	720	80	6500	10000	9232	0.1353	0.349	9.86	0.022	16.8
Factory p\2	7.3	840	240	1250	2200	140	0.1522	0.128	0.465	0.027	472
Factory p\3	7.6	140	340	600	1600	220	0.0993	0.144	1.96	0.03	11.6

Table (1) quality of wastewater generated from paints factories

Source: fieldwork 2019

It is clear from the data in Table (1) that the quality of wastewater resulting from the sample of the paints factories does not bear any indication of physical contamination. As the concentration of total suspended solids and total dissolved solids, in addition to the pH originated in all factories within the scope of the instructions of standards. In the measurements that were taken, for each of the organic properties, chemical compounds and elements, there were indications of organic and chemical pollution. The severity of each varies from one factory to another. The details of which are listed below:

1. The measurements of organic properties in the wastewater of the factory (p/1) were high in concentration, especially the concentration of biological oxygen demand. Biological oxygen demand had a concentration of 6500 mg/liter, exceeding 6150 mg/liter from the instructions of the standard. The chemical oxygen demand had a concentration of 10000 mg/liter, an increase of 9750 mg/liter more than the standard, and the concentration of oils and greases reached 9232 mg/liter, with an excess of 9212 mg/liter from the instructions of the standard which specified only 20 mg/liter. As for the concentration of heavy elements, it exceeded the instructions specified by the standard except for copper measurements. The concentration of lead was 0.1353 mg/liter, while the standard specified 0.1 mg/liter. The concentration of manganese was 0.349 mg/liter, while the standard specified 0.1 mg/liter. Iron concentration reached 9.86 mg/liter, while the standard is 2 mg\ liter. Sulfides provided an indicator of chemical pollution, as their concentration reached 16.8 mg/liter, while the standard set is 2 mg/liter (as the maximum standard permissible by law).
2. Wastewater of the factory (p/2) in which the concentration of chemical oxygen demand increased, its concentration reached 2200 mg/liter, exceeding the instructions of the standard by 1950 mg/liter. The concentration of biological oxygen demand reached 1250 mg/liter, an increase of 900 mg/liter over the standard specification. The concentration of oils and fats reached 140 mg/liter, while the standard specified is 20 mg/liter as the maximum permissible. The iron and copper concentration came within the range of instructions of the standard. The lead concentration reached 0.1522 mg/liter, exceeding the amount of 0.522 mg/liter from the instructions of the standard. The manganese concentration reached 0.128 mg/liter exceeding the instructions of the standard that specified 0.1 mg/liter as the maximum permissible. The concentration of sulfides was 472 mg/liter while the standard set was 2 mg /liter.
3. Wastewater produced by the factory (p/3) in which the concentration of chemical oxygen demand reached 1600 mg /liter, while the standard specified is 250 mg /liter. The concentration of biological oxygen demand reached 600 mg/liter, while the standard specified is 350 mg/liter. The concentration of oils and fats reached 220 mg/liter, an increase of 200 mg/liter over the standard that specified 20 mg/liter as the maximum permissible. For the elements, their concentration was within the permissible range, with the exception of manganese. Its concentration reached 0.144 mg/liter, while the standard specified is 0.1 mg/liter. For the sulfides, they reached a concentration of 11.6 mg/liter, with an excess of 9.6 mg/liter above the instructions of the standard.

By comparing the concentrations of wastewater pollution indicators in paint factories, we find that they differ from one factory to another. The wastewater of the (p/1) plant is more polluted, so the concentration of biological oxygen demand, chemical oxygen demand, oils and greases, in addition to the concentration of iron, lead and manganese is much higher than what is in other factories. The study attributes the problem causing the high concentrations found in plant (p/1) because it specializes in the production of oil paints, where the main raw materials are synthetic oils. The production of this type of paint exceeds that of any other factory, particularly since both other manufacturers combine their production processes for water and oil paints.

Solid waste management

The field study showed that the paint factories produce various solid waste, such as paper, cardboard and plastic waste, there were also traces of damaged raw materials and produced paints in the solid industrial waste.

Hazardous waste	Repetition	The ratio	Bullish relative frequency
Yes	3	100	100
No	0	0	100
Total	3	100	

Table (2) Hazardous solid waste

Source: fieldwork 2019

With regard to the properties of solid industrial waste resulting from paint factories, Table (2) shows 100% of sample factories generated solid waste characterized by dangerous halogenated solvents and sludge. These occur from removing paint, adhesives, and gums. Regarding the treatment of hazardous solid waste, the study revealed that from the sample of paint factories, they do not treat their hazardous waste before its final disposal.

Table (3) Disposal of solid waste in landfill

Disposal of waste in landfill	Repetition	The ratio	Bullish relative frequency
Yes	3	100	100
No	0	0	100
Total	3	100	

Source: fieldwork 2019

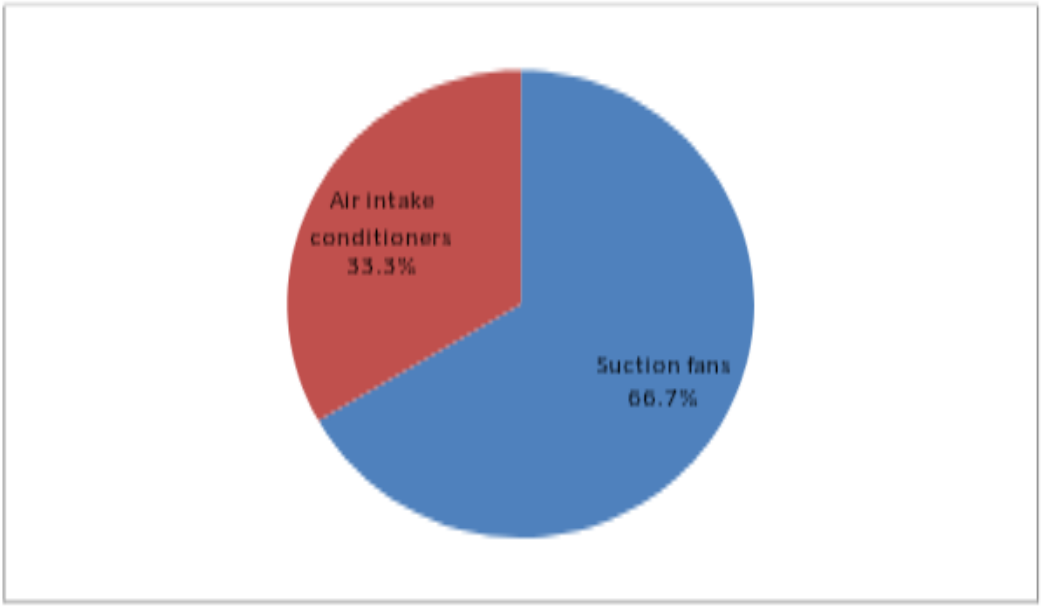
In terms of solid waste disposal methods, the study revealed that the paint factories dispose of their solid waste, including hazardous waste to the landfill. Table (3) shows that all the study sample factories (100%) use the landfill method to dispose of solid waste. This is also the case for disposing of all solid paper and plastic waste, in addition to the leakage of raw materials, halogenated solvents and sludge. The study also showed that on a daily basis, cleaners in each factory collect the waste without first removing the hazardous waste and placing it in special containers in the factory. The Khartoum State Cleaning Company takes over the transfer and disposal of the waste in exchange for a **specific monetary amount.**

Air pollutant management

The study showed that the sample of paint factories does not emit gases resulting from the burning of petroleum derivatives, as the industry relies mainly on electrical energy from the National Electricity Authority for all production processes, However, they release volatile organic compounds and dust into the air.

During the field visits the researcher noticed that there was spray released from the water-based paint mixer and the oil-paint mixer during their use inside the production halls. Dust was also emitted from the mixing of water-based paint materials and the grinding process of oil paint powder. Regarding methods for the reduction of air pollutants inside the production halls, the study revealed that the factories' samples use two key methods illustrated in Figure (1).

Figure (1) Procedures for reducing pollution.



Source: fieldwork 2019

Figure (1) show that 66.7% of the study factories use suction or exhaust fans to extract pollutants out of the production halls. There is 33.3% of the sample which showed that air conditioners were used to limit the spread of pollutants. The study considers the use of exhaust fans and air conditioners to reduce air pollution as ineffective. The results of the accurate particulate matter

measurements of these factories indicate a significant increase in their concentration. There is also a spread of pollutants outside the production units, which leads to air pollution inside and outside the production units (see Table 4).

Table (4) the results of measuring the concentration of fine suspended particles.

Occupational health instructions		10 mg/m/hour	Notes
Factory	Measurement site		
(B/1)	Production hall	26mg/m/hour	Sixteen higher than instructions
(B/2)	Production hall	19mg/m/hour	Nine higher than instructions
(B/3)	Production hall	25mg/m/hour	fifteen higher than instructions

Source: fieldwork 2019

Table (4) show that the concentration measurements of fine suspended particles in the working environment of the paint factories exceed the safe limit set by the Occupational Health Administration. The concentration of particles in the production hall in the factory (p/3) reached 26 mg/m3/hour exceeding the 16 mg/m3/hour health instruction. In the factory (p/ 2), the concentration reached 25mg/m3/hour, 15 mg/m3/hour more than the professional standards. The concentration in the factory (p/1) reached 19 mg/m3/hour, exceeding the safety limit by 9 mg/m3/hour.

Environmental management

In terms of the environmental management of industrial waste, the study revealed that all the sample factories do not have a specialized department or a functional structure responsible for managing industrial waste. They also do not meet any administrative and legal practical aspects that aim to improve environmental performance and achieve environmental quality, by reducing the negative environmental impacts of production processes in all stages. They also do not attempt to prevent or limit the residue effects, especially with regard to the process of collecting and transporting industrial waste to its final disposal. Regarding environmental monitoring, the study indicated that all the sample factories do not carry out regular environmental monitoring, including measurements and checks of the quality of industrial wastewater. They also do not monitor and measure the concentration of fine suspended particles and volatile materials in the air in the production units.

Conclusion

This study has found that the factories in the Sudanese paints industry sector lack a suitable integrated environmental management plan for the regulation and control of industrial waste that would prevent or limit the production of industrial pollutants in the environment. This plan would also have guidance on how to make use of pollutants whenever possible and a clear treatment plan for pollutants or residue that cannot be used before its final disposal. Currently, all waste is not treated and is discharged into the sewage network disposal lines. This process does not adhere to the instructions of the Sudanese standard for industrial wastewater and leads to damage in the main network lines and the explosion of the drainage streams. This is mainly down to the accumulation of grease inside the pipes and the subsequent formation of a negative environmental medium for wastewater.

In addition to this, is the increased burden and pressure on the main sewage station network in the Wad Dafiaa area. The wastewater that arrives here contains oils, fats, and trace elements, including Lead, Manganese, and Iron. It also contains fine suspended particles and volatile organic materials which should be treated in the factories. Solid waste is also dealt with in ways that cause harm to the environment. Waste disposed into the landfill contains untreated hazardous materials such as halogenated solvents and sludge. Finally, air pollution inside the working environment and the exposure of workers to the risk of disease is a problem. This is due to the release of chemicals into the air that could be termed - highly dangerous. The most dangerous is the release of organic solvent spray which leads to impaired lung function,[13] and negative nervous system effects and impaired brain function. Air pollution outside the production units is also a problem that needs to be studied and tackled as part of an integrated environmental management plan.

Recommendations

Below is a list of recommendations to support industrial waste management in the paints industry sector in the Khartoum North Industrial Area:

1. The need for the paints industry sector to follow an integrated environmental management plan for the processes that take place in their factories. This guarantees the prevention or reduction of internal and external pollution resulting from production processes.
2. It is important to create a department in each factory which is concerned with the management of industrial waste, so that it handles the waste treatment in a way that meets the compliance of the Sudanese standard specifications/instructions, before final disposal and in an environmentally safe manner, in addition to making the most of the waste.
3. A requirement for factories to agree to regular environmental reviews and periodic environmental measurements of indoor and outdoor air pollutants in their production units. They should also be done for wastewater measurements and making sure to compare results with the standard specification to meet compliance with the requirements of the standards. Also, to highlight where deficiencies occur and to work towards addressing them to reach satisfactory environmental quality standards.
4. The need for coordination between ministries concerned with environmental affairs to deliver support and guidance to the factories to reconcile their environmental status. The aim is to protect the environment, not to manage violations by fines and levies alone.
5. To activate the role of the Labor Culture Foundation, especially in the field of worker health and safety. They can support the industry by educating workers about the risks they are exposed to in the work environment, as well as training them in the safe handling of industry inputs and outputs in a manner consistent with occupational health and safety requirements.
6. The necessity for factories to keep abreast of global developments in the field of pollution control, especially if environmentally committed factories find wider and wider international markets for their products, there is still a need to become more environmentally friendly.
7. To encourage and fund scientific research and studies in the field of preventive measures for industrial pollution from its sources.

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