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REVIEW

Environmental waste management in mechanical workshops: towards a culture of urban sustainability

Gestión ambiental de residuos en talleres mecánicos: hacia una cultura de sostenibilidad urbana

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ABSTRACT

The study examined the environmental impact generated by auto repair shops, focusing its analysis on the inadequate management of hazardous waste such as lubricating oils, batteries, and polluting filters. National and international background information was reviewed, which showed poor performance by auto repair shops in terms of waste management, in many cases without complying with current environmental regulations. Various studies concluded that waste was disposed of in the environment without prior treatment, seriously affecting water, air and soil. Structural causes were also identified, such as lack of information, limited budgets, absence of municipal permits and poor enforcement by the competent authorities. Alternative solutions were explored, such as the application of bioremediation techniques using microorganisms and the use of activated biochar, which proved effective in restoring contaminated soils. The theoretical framework included the Battelle-Columbus theory and fundamental concepts of ecology and environmental psychology, providing an understanding of how human perceptions and behaviours influence sustainability. The regulatory analysis demonstrated the existence of environmental laws but highlighted their limited application in practice. It was concluded that the environmental management of these establishments required not only sanctions and control but also a cultural and educational transformation that would promote collective sustainable behaviour.

Keywords: Environmental Impact; Hazardous Waste; Mechanical Workshops; Bioremediation; Sustainability.

RESUMEN

El estudio examinó el impacto ambiental generado por los talleres mecánicos, centrando su análisis en la gestión inadecuada de residuos peligrosos como aceites lubricantes, baterías y filtros contaminantes. Se revisaron antecedentes nacionales e internacionales que evidenciaron una deficiente actuación por parte de los talleres en cuanto al manejo de sus desechos, en muchos casos sin cumplir con la normativa ambiental vigente. Diversas investigaciones concluyeron que los residuos eran eliminados en el entorno sin tratamiento previo, afectando gravemente al agua, aire y suelo. También se identificaron causas estructurales, como la falta de información, presupuestos limitados, ausencia de permisos municipales y escasa fiscalización de las autoridades competentes. Asimismo, se exploraron alternativas de solución, como la aplicación de técnicas de biorremediación con microorganismos y el uso de biocarbón activado, que demostraron ser eficaces en la restauración de suelos contaminados. El marco teórico incluyó la teoría Battelle-Columbus y conceptos fundamentales de la ecología y la psicología ambiental, permitiendo comprender cómo las percepciones y conductas humanas influían en la sostenibilidad. El análisis normativo demostró la existencia de leyes ambientales, pero subrayó su limitada aplicación en la práctica. Se concluyó que la gestión ambiental de estos establecimientos requería no solo sanción y control, sino también una transformación cultural y educativa que favoreciera una conducta sostenible colectiva.

Palabras clave: Impacto Ambiental; Residuos Peligrosos; Talleres Mecánicos; Biorremediación; Sostenibilidad.

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INTRODUCTION

The present analysis examined the environmental impact generated by auto repair shops, with a focus on the inadequate management of hazardous wastes, including lubricating oils, batteries, and other industrial waste. Several national and international studies were reviewed to establish a clear picture of the magnitude of this problem. The research identified that, in many cases, the workshops did not comply with current environmental regulations, either due to a lack of knowledge, economic limitations, or inadequate oversight. It highlighted the seriousness of the damage that a single liter of oil can cause to water and soil, as well as the detrimental effects on human health and biodiversity. In addition, proposed solutions were explored, including the application of bioremediation through microorganisms and the use of activated biochar for the remediation of contaminated soils. Environmental theories, such as those from Battelle-Columbus, and key concepts of environmental psychology were also reviewed to understand the relationship between human behavior and ecological deterioration. The regulatory framework, both national and international, was also considered, highlighting the need for its practical application to achieve sustainable changes. This analysis enabled the recognition that the problem extended beyond physical pollution to include a lack of environmental awareness and a weak culture of prevention and sustainability within the automotive sector.

DEVELOPMENT

Hurtado et al.[1], presented the objective of analyzing lubricant management in Chota Cajamarca using a quantitative, cross-sectional, descriptive design approach. As a result, the monthly projection for the total number of workshops is 2918,36 gallons of lubricating oil used. This means a significant amount of waste, as each liter of used oil has a substantial impact on the environment. It was concluded that none of the mechanics in the sample complied with environmental standards. Similarly, Perez[2] sought to determine the ecological impact of waste management in mechanics in Miraflores Arequipa. He applied a quantitative approach in his study, using a causal correlational descriptive level. As a result, 59 %, 93 %, and 93 % of the respondents believe that the workshop where they work generates waste in the form of lubricating oil, brake fluid, and coolant, respectively. It was concluded that they dispose of 15 gallons of waste liquid, including lubricant, brake fluid, and coolant, as well as solid waste, such as oil filters, fuel, air, various types of containers, and batteries.

Similar to the above, Bendezú[3] proposed an environmental plan to minimize the quantities and risks of workshop waste in the Ica area. He used a qualitative-observational approach methodology with a cross-sectional descriptive design. As a result, 66 % of the analyzed workshops do not have current municipal permits because the procedures are complex, they lack knowledge of the law, and they have limited budgets. He concluded that the inefficient management of workshop waste is due to a lack of laws, poor environmental planning, and inadequate municipal control. He sought to investigate the bioremediation of soils contaminated by mechanical workshop waste. He employed a qualitative approach with a narrative design. Its results "determined that such Pseudomonas Aeruginosa, Micrococcus luteus, Enterococcus faecalis, Bacillus subtilis, Proteus vulgaris, Shigella flexneri, Serratia marcescens, Lysinibacillus sphaericus degraded engine oils in a range of percentages from 84,6 % to 94 %". Presenting a solution option to the mechanical waste problem that significantly harms the world. It was concluded that the most effective microorganisms for removing mechanical wastes from soils were Pseudomonas aeruginosa, Acinetobacter, and Bacillus.

In addition, Rodney et al.[4], proposed an objective to analyze the effect of activated biochar from Persea americana Pepa, swine manure, and poultry manure on soils contaminated by hydrocarbons. It implemented a methodological approach of an applicative type with a quantitative focus, utilizing a pure experimental design at the explanatory level. In the results, the sample presented an "initial soil TPH of 10041,0 mg/kg, changes are observed in each phase 1 (7 %) which reduced to 7504,2 mg/kg, phase 2 (7 %) reduced to 5824,2 mg/kg, phase 3 (7 %) reduced to 4700,0 mg/kg". This indicates that this group of organic elements makes a significant contribution to the restoration of soils damaged by negligent mechanical waste management. It was concluded that the use of activated biochar from swine manure and chicken manure removes most of the hydrocarbons in soils.

International background

Arciniega et al.[5] aimed to investigate the management of hazardous waste from mechanical workshops in Mochis, Sinaloa. With a basic type methodology, a quantitative approach using a non-experimental cross-sectional design. As a result, all the seminars in the sample discarded waste oils and liquid; additionally, the majority (86 %) discarded batteries at some point. In conclusion, there is a group of mechanics that disobey the law regarding hazardous waste management.

Likewise, Aguirre et al.[6] sought to understand the current state of knowledge and management of leftover waste from the mechanical workshop in Santa Cruz de Lorica. They employed a basic methodology with a quantitative approach, a non-experimental design, and a descriptive scope. As a result of the sample, 74 % produce between 1 and 4 gallons of used oil per month, and the rest produce between 5 and 9 gallons per month, reaching a maximum of 408 liters of liquid waste per year. It was concluded that the analyzed businesses negligently discard waste in common dumps or the environment. They ignore their level of contamination.

Additionally, Molina et al.[7] presented the objective of determining the environmental impact of waste from workshops in Jipijapa, Ecuador. They used a basic methodology with a qualitative approach, non-experimental design, and documentary analysis. The results identified a methodological framework for generating environmental knowledge. It was concluded that having a greater interest in both university and municipal leaders would benefit the research related to the environmental impact of businesses. Also, the development of new ordinances and laws that encourage and control the management of hazardous waste.

Similarly, Bedón[8] aimed to analyze waste pollution from vehicle maintenance activities and propose a sustainable solution. His methodology was of a bibliographic, observational, and descriptive transversal type. As a result, it was found that the largest producers of hazardous waste, such as lubricating oil and filters, are mechanical workshops. It concluded that poor practices in waste

management in garages can be a serious problem for people and the entire world, as the capacity of a drop of water can affect 1 000 liters of water.

Similar to the above, Gonzalez et al.[9] aimed to analyze the management of waste from the MVS, its impact on the environment, and the causes that give rise to this problem in Guasave, Mexico. With a basic methodology of a mixed approach, utilizing a non-experimental design at the correlational level. As a result, it was found that the mechanics do not comply with environmental regulations due to two reasons: low income and ineffective control by the responsible bodies. It has been determined that most maintenance shops have inadequate waste management, particularly among micro-businesses. On the other hand, few businesses comply with environmental regulations; notable exceptions include automotive subsidiaries and agricultural machinery manufacturers.

Theoretical Framework

Battelle-Columbus Theory

This methodology originated in the United States at the Battelle-Columbus laboratory, where its objective was to measure the environmental impact of water plant projects or actions. However, it also presented the possibility of adapting to other types of projects. This method had "78 environmental parameters classified according to 18 environmental components, which in turn are grouped into four environmental categories."[10] Through the development of the formula, values can be obtained that represent the net environmental impact of the business activity.

Ecology

According to Norbert et al.[11], ecology refers to the organisms that belong to a habitat, along with their chemical characteristics and various processes that intervene in their daily lives. This generates a natural system. Likewise, in 1869, Ernst Haeckel used the term "ecology" for the first time; in his study, he proposed that it had Greek roots, as he derived it from Oikos (house) and logos (study). He interpreted ecology as the relationships between living beings and their homes.[12] In the opinion of Jiménez et al.[13], ecological studies examine the interrelationships of beings within an ecosystem and their impact on it. Ecology analyzes the relationships between living organisms within an environment. Understanding that such science encompasses physical, biological, technological, and social factors due to their influence on living beings.[14] Similarly, it examines the mechanisms that regulate the life of the organism, seeking to understand the relationships and impacts of species on their environment.[15]

Species and populations

Species are indicators of a healthy environment because they are economically or recreationally valuable to humans. Human activity changes the global ecosystem because it affects terrestrial, aquatic, and aerial areas, transforming the environment into an industrial one. Today's society seeks progress, creating and building huge businesses that have an impact on the environment.[11] Likewise, the population is defined as a group of organisms with the same biological characteristics, which generates a high level of reproduction crucial for the survival of their species. Additionally, they share the same time and place, characterized by heterogeneous resource availability.[16]

Contamination

According to Norbert et al.[11], an ecosystem is a system of related parts; therefore, it is necessary to consider these parts when developing a production system, as poor management will result in damage to all. Urban air pollution is primarily caused by land-based vehicles and business activities. The primary pollutants are emissions from both industrial and automotive activities. However, the secondary pollutant is the transformation of the primary pollutant when it interacts with atmospheric components, highlighting photochemical pollution and acidification.[17] Water is considered contaminated if its composition does not allow it to be used for its intended purpose.[18] Likewise, Dolores[19] considers contamination to be unwanted substances with dangerous quantities present in natural resources, making regular use for human consumption impossible.

Soil

According to Norbert et al.[11], land is considered an essential element for humans, as cities, business activities, and territorial distinctions are developed on it. The basic author states that it serves "for agricultural production, residential and industrial development, resource development and conservation of open spaces". He highlights its value due to its essential role in the development of a society. Additionally, the Universidad Nacional de la Plata[20] defines soil as the most superficial layer of the Earth, formed by erosive actions and biological activities. It is also varied and multifaceted, as it receives all-natural actions, as well as the effects of climate change. According to Hillel in the Ministry of Agriculture[21], the importance of the resource is based on its capacity for absorption, decomposition, and regeneration of life.

Noise

Noise pollution is produced by man and nature whenever it has a physical effect. Nowadays, it is considered a more significant environmental stressor.[11] Noise is understood as the interference in the perception of a sound with a value.[22] It is one of the most present polluting factors in "Mechanical work, maintenance work, construction and mining work, welding, manufacturing industry activities, and food industry work." It is a stressor for ordinary citizens or the surrounding population due to the noisy activities. Additionally, the Instituto de Salud Pública[23] defines noise as the time a worker is exposed to noise during their working day, representing a risk of hearing loss.

Aesthetic Aspects

It aspires to work in places that do not harm natural features appreciated by society, seeking an equitable exchange between development and the environment. Due to the fact that stress levels have been increasing in recent years, outdoor recreational activities are of great help for mental health.[11] Likewise, Aguilar[24] notes that symbolically speaking, the landscape represents the progress of the modern world from the perspective of each subject. Similarly, Martí[25] expresses that the landscape, together with the environment, is considered a factor that influences health due to its emotional qualities. In different parts of the world, some laws do not sanction damage to the aesthetic aspect, as it is the responsibility of the state.

Soil

The location of companies is a relevant factor in business activity, as it varies significantly. "A reservoir located in plains is scenically less attractive than one nestled in high mountains".[11] The aesthetic aspect influences business activity, as it can impact consumer preference. Also, soil is an element that interacts with the atmosphere and the layers below it. According to Jaramillo[26], it is an element of great value because it "influences the climate and the hydrological cycle of the planet and serves as a growth medium for a varied community of living organisms". Its main activity is the decomposition and regeneration of life. Likewise, the soil is the result of alterations in rock due to contact with the atmosphere and the accumulation of materials in the lower zones of the terrestrial layers. As time passes, the minerals and the living organisms that inhabit them change.[27]

Air

Air is the most attractive component of the environment as long as it is free of pollutants. Its deterioration generates discomfort in the sight and smell of the being. Excess humidity intensifies the temperature and even makes breathing difficult.[11] Air pollution causes acids that, with rainfall, lead to harmful effects on water, flora, and fauna, as well as the loss of crops and soil fertility.[28] Likewise, Rojas et al.[29], particulate matter is solid and liquid particles of minute size with an aerodynamic diameter of less than 10 µm that travel through the atmospheric environment and enter the respiratory system, causing damage to people exposed to them.[30,31]

Aspects of Human Interest

It is an element that enhances the internal well-being of the human being, particularly in terms of emotional life. It contributes to the tranquility and joy of the person in society.[11] Chuquitarco[32] express that the "social vision takes into account historical facts of civil society in general". It belongs to the culture of each place since it informally governs the daily activities of society.

Educational and scientific values

According to Norbert et al.[11]. They give importance to places that have some educational or scientific value. Places with natural processes. Such places have greater value in terms of transmitting knowledge. "how do earth processes work now, or have they worked in the past? How did prehistoric people live, what kinds of prehistoric animals lived, etc." They serve as lessons for the future. Current teaching methods ask young people to seek and transform knowledge.[33] Using research techniques and systems, they form a professional with greater capacity in their specialization.

Sensations

According to Norbert et al.[11]. Emotions are a highly valued part of the human experience; anger, sadness, joy, and displeasure are complex states to measure but profoundly influential in the life of each individual. As stated by the Department of Health Psychology, these are processes that occur within the person. "Sensation is the primary brain processing coming from our main senses".[34] According to the five elementary senses, a stimulus is obtained from the outside. Sensations arise through the processes within each person. "For that, we have receptors in the skin, in the retina, in the tongue, and all the senses to collect all the information." Physically, we interpret our environment and understand if it is beneficial or dangerous.[35]

Environmental Impact of Mechanical Workshops

Environmental impact

Environmental change is understood as the alteration of the environment produced by human activity. It is stated that human beings are responsible, directly or indirectly, for development, which groups within society often prioritize.[36] Likewise, Vera[37] express that they are the environmental changes that would exist with the execution of the project and without its execution. Finally, Senate[38], "Positive or negative alteration of one or more components of the environment, caused by the action of a project". Refers to a positive or negative change in the environment caused by a project of human activities.

Environmental impact on air

The operation of diesel inside the engine produces soot that immediately oxidizes, from which a thousandth part is emitted to the outside, comprising a combination of carbon monoxide (CO), nitrogen oxides (NOx), unburned hydrocarbons (HC), and sulfur dioxide (SO2). Although shown in minute quantities, the total number of vehicles worldwide represents a significant problem. The damage to human beings and the ecosystem is irreversible; hemoglobin loses the property of transmitting oxygen, just as the emission of gases accelerates the greenhouse effect.[39] Concentrations higher than 0,3 % CO by volume are toxic and potentially lethal. The lack of oxygen in engine operation generates carbon monoxide, and the sulfur in the fuels is transformed into sulfur dioxide, which causes pungent odors and acid rain.[40]

Environmental impact on water

According to Gonzales et al.[41], in Peru, a report was presented indicating the exceedance of the arsenic limit in drinking water in several districts of Lima, "in twelve districts, of which 86 % exceeded 10 ug/L, and 56 % exceeded 50 ug/L". Having as reference the maximum mark of this element with 10ug/L proposed by the World Health Organization (from now on "WHO"). Guadarrama et al.[42], water pollution is understood as a change in the quality and chemical composition of water due to the presence of a foreign entity, which alters its use and renders it unsuitable for the intended purpose. The mixture of microorganisms, chemical products, industrial wastes of other types, or wastewater negatively affects its composition and subsequent use for development activities.[43]

Environmental impact on soil

According to Junceda[44], change occurs due to various sources, including "dumping, emissions or incorrect deposition". Rural and industrial activities transform the composition of the environment. It is degradation due to the presence of chemicals. The excess of these reduces their use for both business activities and for nature itself. It plays a vital role, as it acts as a filter that retains some toxic compounds on the surface and allows others to continue with the water found deeper.[45]

Waste Management

According to Ramírez et al.[46], there is an uncontrolled system of production, consumption, and waste. Products of industrial and domestic use accumulate in landfills, which can have a significant impact on the environment. These are all products, whether solid, semi-solid, liquid, or gaseous, that had a use for their carrier and later ended up in the waste because it is considered that they have fulfilled their function and have no further value.[47] According to Martinez[48], hazardous waste exhibits characteristics such as "toxic, corrosive, reactive, flammable, explosive, infectious, ecotoxic". Tacitly presenting itself as a danger to the person exposed to it. The generators of hazardous waste are obligated to dispose of these carefully or otherwise establish agreements and facilitate the process for those who manage them.[49] Workshop waste greatly harms the environment and society. Bedón[8], explains that hydrocarbons destroy the components of the environment in which they are discarded, are highly hazardous, and instantly alter natural properties, weakening their defenses and their ability to reproduce. Likewise, oils that enter water surfaces do not dissolve; instead, they form films that prevent the entry of oxygen, leading to poisoning and infertility in the ecosystem.

Environmental Provisions or Laws / Environmental Impact

General Environmental Law No. 28611[49], affirms that everyone has the right to live in an environment that allows them to develop, protect the environment, ensure the safety of people individually and collectively, and conserve biological diversity. Likewise, Law 27446, Law of the National System of Environmental Impact Assessment,[50] SEIA "aims to identify, prevent, monitor, control and correct environmental impacts", seeking a measured use of resources and care for the environment, extending the maximum possible capacity of natural resources. Also, according to Law 25238, the Review Commission of the Draft Code of the Environment and Natural Resources was created, which indicates that any public or private activity that represents a danger to the environment will first be evaluated by an Environmental Impact Assessment (EIA), subject to the corresponding authority.[51]

Environmental Psychology

According to Hernández[52], this is an environmental field that focuses on the relationship between people and the environment, specifically examining the behaviors that cause ecological damage or contribute to its conservation. It aims to determine the processes that lead individuals to perform in specific ways within the environment, which uncovers the "environmental perceptions, attitudes, evaluations, and representations".[53] Present in each individual and society. Similarly, Corral et al.[54], suggest that the analysis of interactions between people and their environment reveals the behaviors of the former that contribute to the development or deterioration of the environment. In this review, "lifestyles that can guarantee the sustainability of socio-ecological systems for present and future generations"are appreciated. Projecting as an objective the survival of the species itself. They have, as a central aspect, environmental conservation and, with it, sustainable conduct that consists of guaranteeing an integrated sustainable development that takes care of resources for future generations.

Sustainable conduct

According to Castro in Puertas et al.[55], these are actions that individually or collectively contribute to environmental care. Likewise, Corral et al.[54] express that they are "acts that avoid consumerism and waste of resources; altruistic actions: behaviors of caring for others without expecting anything in return", showing a transcendent action by seeking a greater purpose than just one's own and passing profit.[56,57,58,59]

CONCLUSIONS

In summary, the research led to the conclusion that waste management in auto repair shops was essentially negligent, resulting in a significant negative impact on the environment's components: air, water, and soil. Most garages did not apply adequate waste treatment practices, failing to comply with current legislation and leaving a worrying ecological footprint. Despite some individual efforts, structural problems, including a lack of technical expertise, inadequate government oversight, and unsustainable incentives, made it challenging to implement practical solutions. However, it became evident that viable alternatives such as bioremediation, the use of activated biochar, and environmental education are key strategies to mitigate the damage caused. It also reaffirmed the importance of promoting sustainable behavior in all the actors involved, from operators to local authorities. Ultimately, it became

clear that environmental care in urban contexts, as exemplified by Comas, necessitated a collective and cross-sectoral commitment that integrated scientific knowledge, community action, and political will.

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