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# QUALITY INDEX IN THE ENVIRONMENTAL MANAGEMENT SYSTEM IN URBAN SOLID WASTE LANDFILLS - IQS

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## ABSTRACT

The article consists of the application of a new rating methodology for final disposal of urban solid waste (USW) by evaluating the conformity of geotechnical and environmental aspects during the implementation and operating processes. The IQS was proposed when introducing the concepts of Environmental Management, in accordance with ISO 14001, to the Landfill Quality Index (IQA) [1], developed from the Waste Quality Index (IQA) proposed by [2]. The study focused on the implementing and operating processes, as well as on the control of impacts on the environment and on pollution prevention. Fifteen sites were assessed to confirm the hypothesis. They were rated as inadequate, controlled, adequate and environmental conditions, in accordance with indices obtained with intervals between zero and ten points. It could, therefore, be concluded that in an inventory of rating USW disposal landfills, the use of ISO 14000 as an analytical tool may be extremely helpful to enhance assessment methods. Moreover, environmental management concepts contribute to reducing environmental pollution and, consequently, the associated environmental impacts.

## KEYWORDS

Urban Solid Waste, Sanitary Landfill, Environmental Management, ISO 14000

## 1 INTRODUCTION

Among the different existing environmental problems, the USW has become one of today's major challenges. The fast growing population requires the production of goods and services, which, in turn, as they are produced and consumed, generate even more waste, their collection and disposal are inadequate and cause significant impacts on public health and the environment.

Waste disposal in landfills is quite common and is the technique most used due to its practicality and low cost. However, landfills cannot be considered merely a place to store waste. They must also be assessed as geotechnical projects, with the behaviour of the different stages of implantation, operation and degradation.

Adequate disposal of USW should be conveniently designed to include concepts relating to the engineering project, knowledge of geotechniques, field investigation and laboratory studies, also covering environmental, economic, political and social aspects, and requires a team of skilled professionals [3].

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The choice of the best site for final waste disposal is an even more complex problem, since it involves such factors as environmental, economic, transport logistics, structural safety and political [3].

[3] also find that the spaces for implementing landfills are becoming ever fewer, since, within the territorial boundaries of the counties, it is hard to choose suitable sites for disposal, which involves a thorough systematic study of various disciplines, such as Geotechniques, Hydrogeology, Hydrology and Climatology.

So this article proposes a set of systematised parameters as basis for structuring and formulating an index relating USW, environment, health and the human being.

Considering the above factors, this proposal was based on the introduction of management requirements, using the standard ISO14001 (Environmental Management System – Specification and Guidelines for use) as a criterion for adapting to the Landfill Quality Index (IQA) [1], through which the proposal is to assess final disposal and treatment of USW from the environmental management viewpoint.

Based on the hypotheses that, considering IQA rating parameters as shown in Tables 1, 2 and 3, a landfill rated "adequate" (or sanitary) by IQA will not guarantee treatment and disposal of its environmentally safe waste; and that the ISO 14000 will be a valuable tool to be used in the landfill rating inventory to verify environmental conditions, as well as aspects relating to the characteristics of the site, its infrastructure and operations.

For example, a landfill with no control, collection and leachate treatment (most significant negative environmental impact) and without effective monitoring of underground water bodies, is IQA-rated as adequate, with score 8.07.

Several underwater water pollution studies show that every uncontrolled landfill causes damage to the environment. Badly built sanitary or controlled, located or operated landfills can alter the quality of aquifers and air and, consequently, contaminate the soil, plants, animals and humans.

Next, the use of ISO 14000 is discussed as a management tool for operating USW landfills. Then the system adopted for evaluating landfills (IQS) is presented.

First, data collected on field visits from twelve USW disposal sites in the States of Rio de Janeiro, two in São Paulo, and one in Pernambuco, were used to apply this rating.

After applying the IQS, the rates obtained were compared analogically with the IQA [1] and IQR rates [2]. With this comparison it was possible to confirm the hypothesis under consideration.

## 2 THE USE OF ISO 14000 IN URBAN SOLID WASTE LANDFILLS

Standard ISO 14001 provided the necessary tools for developing the methodology, and certification requirements could be properly applied to the activities and processes of a sanitary landfill. The soil and subsoil management concept was also applied, consisting of erosion control, salinisation, desertification, proper handling of solid waste, and restoring degraded areas.

*Table 1: Characteristics of site [1]*

| LOCAL CHARACTERISTICS | | |
|---|---|---|
| Capacity to support soil | Adequate | 5 |
| | Inadequate | 0 |
| Permeability of soil | Low | 5 |
| | Medium | 2 |
| | High | 0 |
| Proximity to housing schemes | far > 500m | 5 |
| | near | 0 |
| Proximity to water bodies | far > 200m | 3 |
| | near | 0 |
| Depth of groundwater | over 3m | 4 |
| | 1 - 3m | 2 |
| | 0 - 1m | 0 |
| Availability of material for cover | Sufficient | 4 |
| | Insufficient | 2 |
| | None | 0 |
| Quality of material for covering | good | 2 |
| | bad | 0 |
| Conditions of road-traffic-access system | Good | 3 |
| | Regular | 2 |
| | Bad | 0 |
| Visual isolation from neighbourhood | Good | 4 |
| | Bad | 0 |
| Legality of location | Permitted entry | 5 |
| | Forbidden entry | 0 |
| **sub-total 1** | **Maximum** | **40** |

*Table 2: Implanted infrastructure [1]*

| IMPLANTED INFRASTRUCTURE | | |
|---|---|---|
| Fencing in the area | yes | 2 |
| | no | 0 |
| Gateway/ Cabin | yes | 1 |
| | no | 0 |
| Control of receipt of cargo | yes w/ weighbridge | 2 |
| | yes /no weighbridge | 1 |
| | no | 0 |
| Access at front of work | good | 2 |
| | bad | 0 |
| Caterpillar tractor or Compatible | permanent | 5 |
| | periodical | 2 |
| | non-existent | 0 |
| Other equipment | yes | 1 |
| | no | 0 |
| Impermeability of landfill base | yes/unnecessary | 5 |
| | no | 0 |
| Drainage of leachate | sufficient | 5 |
| | insufficient | 1 |
| | non-existent | 0 |
| Definitive storm water drainage | sufficient | 4 |
| | insufficient | 2 |
| | non-existent | 0 |
| Temporary storm water drainage | sufficient | 2 |
| | insufficient | 1 |
| | non-existent | 0 |
| Gas drainage | sufficient | 3 |
| | insufficient | 1 |
| | non-existent | 0 |
| Leachate. treatment system | sufficient | 5 |
| | insufficient/non-exist. | 0 |
| Monitoring underground water | sufficient | 3 |
| | insufficient | 1 |
| | non-existent | 0 |
| Monitoring das surface water, leachate and gases | sufficient | 3 |
| | insufficient | 1 |
| | non-existent | 0 |
| Monitoring soil and waste embankment | sufficient | 3 |
| | insufficient | 1 |
| | non-existent | 0 |
| Fulfils design stipulations | yes | 2 |
| | partly | 1 |
| | no | 0 |
| **sub-total 2** | **Maximum** | **48** |

*Table 3: Working conditions[1]*

| OPERATING CONDITIONS | | |
|---|---|---|
| Presence of wind-borne elements | No | 1 |
| | yes | 0 |
| Daily waste cover | yes | 4 |
| | no | 0 |
| Waste compaction | Adequate | 4 |
| | inadequate | 2 |
| | non-existent | 0 |
| Presence of vultures-gulls | no | 1 |
| | yes | 0 |
| Presence of large quantity of boulder clay | no | 2 |
| | yes | 0 |
| Presence of burnings | no | 1 |
| | yes | 0 |
| Presence of waste collectors | no | 3 |
| | yes | 0 |
| Livestock (cattle, etc.) | no | 3 |
| | yes/nearby | 0 |
| Health service waste dumping | no | 3 |
| | yes | 0 |
| Industrial waste dumping | no/adequate | 4 |
| | yes/inadequate | 0 |
| Functioning leachate drainage | Good | 3 |
| | Regular | 2 |
| | non-existent | 0 |
| Functioning definitive storm water drainage | Good | 2 |
| | Regular | 1 |
| | non-existent | 0 |
| Functioning temporary storm water drainage | good | 2 |
| | regular | 1 |
| | non-existent | 0 |
| Functioning gas drainage | good | 2 |
| | regular | 1 |
| | non-existent | 0 |
| Functioning leachate treatment system | good | 5 |
| | regular | 2 |
| | non-existent | 0 |
| Functioning underground water monitoring system | good | 2 |
| | regular | 1 |
| | non-existent | 0 |
| Functioning surface water, waste and gas monitoring system | good | 2 |
| | regular | 1 |
| | non-existent | 0 |
| Functioning embankment stabilising monitoring | good | 2 |
| | regular | 1 |
| | non-existent | 0 |
| Corrective measures | yes/unnecessary | 2 |
| | no | 0 |
| General data about landfill | yes | 1 |
| | no/incomplete | 0 |
| Maintenance of internal access | good | 2 |
| | regular | 1 |
| | very bad | 0 |
| Landfill shutdown plan | yes | 1 |
| | no | 0 |
| **sub-total 3** | **maximum** | **52** |

When administrating a solid waste sanitary landfill using an environmental management culture, committed to prevent and reduce pollution, and employing properly trained skilled manpower, it is essential to adopt an environmental management system that includes an organizational structure, planning activities, responsibilities, practices, procedures, processes and resources to comply with an established environmental policy

This system can be certified, which shows stakeholders how seriously this administration deals with the environmental question; however, ISO 14001 certification does not necessarily imply good environmental performance of the practices, processes, and compliance with the established environmental policies, as provided by ISO 14031. This standard was not used in this study, since the environmental performance assessment (EPA) is only specific for each landfill, when the objective was to have a general rating for them all.

The purpose of certification is to attest that the management system can produce results but without specifying the velocity at which these results will appear. This mistaken routine may lead waste processing to polluting practices, even though the environmental management system is in operation.

## 3 LANDFILL ASSESSMENT SYSTEM

Not only the social but also the environmental, sanitary and public health aspects are to be considered [3]. The Value Analysis Theory was therefore used [4] as a multi-criterion comparative analytical tool for the coherent converging of these variables, creating weights for the different aspects addressed, and then the Quality Rating of the Environmental Management System for Urban Solid Waste Landfills (IQS) was established.

Considering the discussion herein, the standard NBR ISO 14001 was divided into ten parameters, as follows:

1. Identification of significant environmental aspects and impacts (A);
2. Objectives, goals and environmental programmes (B);
3. Guarantee of necessary resources – humans, technological and financial (C);
4. Training system – competence, consciousness – internal and external communication (D);
5. Control of SGA documents, registration (E);
6. Emergency plans and programme (F);
7. Control, monitoring and measuring of operations – relating to significant impacts (G);
8. Meeting legal and other approved requirements (H);
9. Internal audit programme (I); and
10. Critical analyses by the administration – considering internal audits, laws, communication, objectives, goals and environmental programmes – corrective and preventive actions – to mitigate impacts (J).

The IQS comprised four groups, the first three being taken from IQA [1] and the fourth added to the rating: Site Characteristics, Implanted Infrastructure, Working Conditions, and Environmental Management System (Table 4).

The first three groups had no alteration and the Value Analysis was therefore not applied. In the last group, when weighting the new parameters, the functions used were the ten listed above, applying the Functional Assessment Matrix (Table 5). This technique permitted each function to be compared with the others, determining at every moment its importance by weighting between 0 and 3 points.

*Table 4: Environmental Management Assessment parameters [5].*

| **ENVIRONMENTAL MANAGEMENT** | | |
|---|---|---|
| Identify environmental aspects and impacts | satisfactory | 5 |
| | insufficient | 2 |
| | non-existent | 0 |
| Environmental objectives, goals and programmes | consistent | 3 |
| | inconsistent | 1 |
| | non-existent | 0 |
| Guarantee of req. resources. | sufficient | 2 |
| | insufficient | 0 |
| Training & com. system | efficient | 2 |
| | inefficient | 0 |
| Control of docs. and records | yes | 1 |
| | no | 0 |
| Emergency programme and plans | sufficient | 4 |
| | insufficient | 2 |
| | non-existent | 0 |
| Control, monit. & measuring of ops. | effective | 4 |
| | ineffective | 0 |
| Complying with legal & other reqs. | yes | 5 |
| | no | 0 |
| Internal audit programme | satisfactory | 2 |
| | ineffective | 1 |
| | non-existent | 0 |
| Critical analyses & cor. & prev. action | consistent | 2 |
| | inconsistent | 0 |
| **sub-total 4** | **Maximum** | **30** |

*Table 5: Functional Assessment Matrix [5]*

| | B | C | D | E | F | G | H | I | J | Total | % | Pt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | A1 | A3 | A3 | A3 | 0 | A2 | H1 | A1 | A1 | 14 | 17.073 | 5 |
| | B | B1 | B2 | B2 | F2 | G2 | H3 | I2 | B2 | 7 | 8.537 | 3 |
| | | C | C2 | C2 | F1 | G1 | H2 | C1 | C1 | 6 | 7.317 | 2 |
| | | | D | D3 | D1 | G1 | H1 | D2 | J2 | 6 | 7.317 | 2 |
| | | | | E | F3 | G2 | H3 | I3 | E2 | 2 | 2.439 | 1 |
| | | | | | **F** | 0 | F2 | F2 | F2 | 12 | 14.634 | 4 |
| | | | | | | G | G1 | G2 | G2 | 11 | 13.415 | 4 |
| | | | | | | | **H** | H2 | H2 | 14 | 17.073 | 5 |
| | | | | | | | | I | J3 | 5 | 6.098 | 2 |
| | | | | | | | | | J | 5 | 6.098 | 2 |
| | | | | | | | | | Total | 82 | 100.00 | 30 |

At the end of the comparison, the weights attributed to each function were added up to determine their percentage in relation to the total weights of all functions. Following the IQA criterion of the maximum five-point scoring, the most relevant functions were given this score and the others with less proportionately.

With the development of this technique, the scoring of the parameters introduced in the IQS was successfully achieved as shown in Table 6.

*Table 6: Final IQS rating [5]* .

| Total (1+2+3+4) | 170 |
|---|---|
| IQS = Sum of scores / 17 | |
| **IQS** | **Assessment** |
| **0 – 6.00** | Inadequate conditions (landfill or dump) |
| **6.01 – 8.00** | Controlled conditions (controlled landfill) |
| **8.01 – 9.00** | Adequate conditions (sanitary landfill) |
| **9.01 - 10** | Environmental conditions (environmental landfill) |

## 4 IQS APPLICATION TO LANDFILLS

The three quality indices (IQR, IQA and IQS) were applied to the 15 (fifteen) waste dumps visited. Part of the area studied among the 12 (twelve) sites visited in the State of Rio de Janeiro corresponds to the middle stretch of the Paraiba do Sul river basin (Figure 1), and the rest to the Greater Rio Metropolitan Region.

The objectives for choosing these sites were: to compare the current results with those obtained previously by [1]; to present the situation in other disposal areas, in order to have a broader view of local waste management in the State of Rio de Janeiro, and to compare its reality with that of other States.

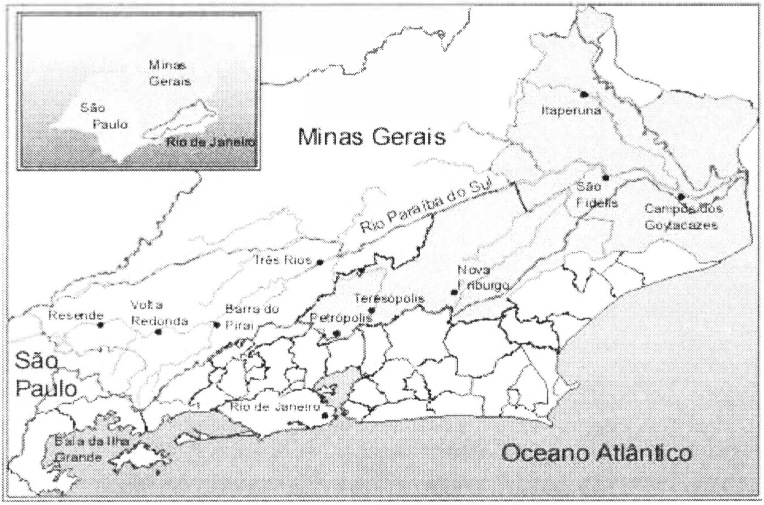


*Figure 1: Rio de Janeiro State and Paraiba do Sul river basin (UNDP, 1999, in [1]Faria, 2002).*

It was decided not to explicitly refer to the sites assessed for political-administrative questions and interests. A more detailed description of the characteristics of the case studies can be obtained in [5]e

In the State of Rio de Janeiro, not only the population of around 2.5 million but also 700 or so industries, various hydroelectricity plants and irrigated agriculture depend on water from this basin. In the Greater Rio Metropolitan Region, approximately eight million inhabitants are supplied from collecting 44 $m^3/s$ from the Guandu River and 5.5 $m^3/s$ from Lajes reservoir, deriving from two transpositions of the Paraiba do Sul river basin. Approximately 160 $m^3/s$ is taken directly from Paraiba do Sul River using the Santa Cecilia pumping station and 20 $m^3/s$ is used from the Pirai river basin [1].

The assessment reports (IQR, IQA and IQS) were completed based on information collected from visual inspections on the sites, some local government data, solid waste landfill operators at each site, professionals in the solid waste sector, and from consulting other reports and papers relating to these landfills.

After accomplishing all work routines, the findings were reported, converging on a weighted average, and a consensus was obtained where each parameter was graded, defining its level of satisfaction, attendance, conformity, effectiveness and/or efficiency.

The main type of soil found in most sites under study was latosol. This soil has a clay fraction of kaolinitic minerals with a high concentration of iron and aluminium. In natural conditions, it is non-saturated, with a high rate of voids and little field capacity, but when suitably compacted it can reach a high supporting capacity with low permeability. These characteristics make the latosol suitable material for daily covering the landfill and base layer and for impermeability [1].

It should also be explained that all sites were called "landfill", regardless of the rating in the assessments, in order of visits.

## 5 ANALYSIS OF RESULTS

During this study, urban solid waste management models were observed in fifteen sites, whose results are given in the Table 7 below.

*Table 7: Result of Landfill Quality Index Assessments [5]*

| Landfill | IQR | IQA | IQS | Rating |
|---|---|---|---|---|
| 01 | 6.62 | 6.86 | 5.76 | Inadequate |
| 02 | 2.31 | 2.36 | 1.94 | Inadequate |
| 03 | 6.15 | 6.43 | 5.53 | Inadequate |
| 04 | 9.62 | 9.50 | 8.71 | Adequate |
| 05 | 3.54 | 3.64 | 3.06 | Inadequate |
| 06 | 7.54 | 7.00 | 5.94 | Inadequate |
| 07 | 8.77 | 9.00 | 9.18 | Environmental |
| 08 | 8.31 | 8.07 | 7.59 | Controlled |
| 09 | 2.77 | 2.64 | 2.35 | Inadequate |
| 10 | 1.08 | 1.07 | 0.88 | Inadequate |
| 11 | 9.08 | 8.86 | 7.88 | Controlled |
| 12 | 4.38 | 4.07 | 3.41 | Inadequate |
| 13 | 2.00 | 1.86 | 1.53 | Inadequate |
| 14 | 6.92 | 7.29 | 6.35 | Controlled |
| 15 | 2.54 | 2.50 | 2.12 | Inadequate |

As can be seen, only one landfill was rated environmental and another rated adequate, which was to be expected, given the strict IQS assessment compared to IQA and IQR. Another three sites were rated controlled and the remaining ten inadequate.

From the landfill rating criteria adopted by IQA and IQR (Figure 2), 46% of the landfills assessed were rated inadequate, 27% controlled and the other 27% adequate. Now considering the IQS assessment criteria (Figure 3), the number of landfills in inadequate conditions increased to 66%, and consequently those in controlled conditions dropped to 20% and adequate to 7%, only 7% remaining rated as environmental.

Accordingly, the proposed methodology showed a 20% increase in the quantity of inadequate landfills (dumps), and a 20% drop in the number of adequate landfills (sanitary), confirming the hypothesis that from the previous methodologies, a landfill in adequate conditions did not necessarily maintain environmentally correct operations.
From examining the following graphs, it could be said that the IQS assessment is most restrictive, since the rating in each case was lower than in the other forms of assessment, except for landfill 07, due to the SGA inserted throughout the waste treatment process and disposal, scoring in environmental parameters not assessed by the other methodologies.

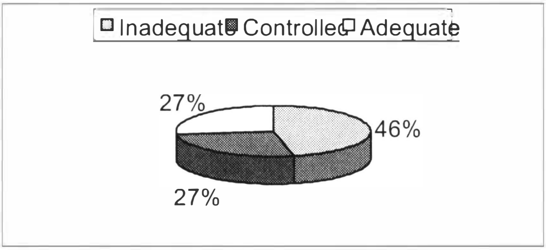


*Figure 2: Rating by IQA and IQR [5]*

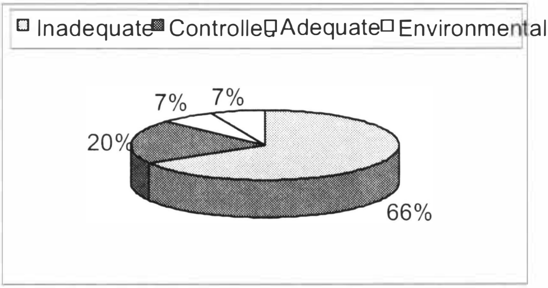


*Figure 3: Rating by IQS [5] (Loureiro, 2005)*

## 6 CONCLUSIONS AND FINAL COMMENTS

Following one of the proposals for continuing the line of research on the Waste Treatment Group (GTRES) in the Geotechnics area of COPPE, the objective of this work was to evaluate the degree of conformity of the rating criteria of USW landfills from the environmental management viewpoint, based on ISO 14001 requirements, in terms of implementation, operation and closure of landfills, and interactions with the environment.

Therefore, by applying the IQS assessment methodology in the fifteen case studies, it was possible to confirm the two hypotheses under discussion: that the IQA adequate rating does not guarantee environmentally secure USW treatment and disposal, and that NBR ISO 14001 is a valuable tool that can be used in a landfill rating inventory.

To fully attend IQS environmental parameters when adopting the NBR ISO 14001 requirements, it is fundamental to continue in compliance with the prevailing environmental laws, and to monitor and maintain previous standards of environmental quality, inherent in the aspects and impacts surveyed in the area next to the landfill. This tool and the other standards of the ISO 14000 family may be used to regulate waste disposal throughout Brazil.

The geotechnical parameters (support and permeability of the soil, availability and quality of cover material, compaction, drainage systems, embankment stability, remediation, closure, etc.) were found to be important in several aspects of final waste disposal, since the landfills will inevitably be based on the ground and may be protected by it using an adequate cover. Moreover, it is of the utmost importance to guarantee environmental quality, proper liner compaction, groundwater depth, and permeability of the foundation soil, since this is the main route taken by liquid contaminant, namely, leachate.

Also, like water, soil is becoming ever more important especially since indiscriminate use of spaces and borrow material for partial or final cover will be increasingly scrutinised, considering not only the environmental but also economic, social and financial aspects.

It should be pointed out that Clean Development Mechanism (CDM) concepts can and should be used in the waste sector as an economic-financial support when implementing and operating sanitary landfills, and adopting compost processes, incineration or other procedures such as drying waste, for example, to reduce greenhouse gas emissions to a minimum. Monitoring procedures, collecting and using gases can be done by burning them to generate energy. These aspects shall be included in the assessment system of midsize and large landfills in future procedures, since they are being discussed and further implemented in Brazil.

Lastly, in addition to the need to use skilled personnel, with know-how and multidisciplinary experience, it must be stressed that different landfill assessment systems should be considered and used in accordance with their different sizes. Basic aspects are similar in small, midsize and large landfills, but there are particular features inherent to the size of a landfill, which recommend major differences in assessment systems. Otherwise, distortions may occur since it may be impossible to adopt procedures that are absolutely possible and necessary in some other large landfill.

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