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1 **Application of risk analysis to improve environmental**
2 **sustainability of water in construction sites**

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7 **Abstract.** Water is pivotal for human life. The sustainable development of
8 goods and facilities should account for its preservation in terms of both quantity
9 and quality. In this paper a brief case study on the water consumption and man-
10 agement of construction sites was presented. By means of a methodology de-
11 veloped by the authors, the process, product and service water exploited in
12 building processes have been analysed. The results show that the water-loss is
13 spread in the different phases of the processes involving machinery, materials,
14 work organization and environment. The tool, coupled with a check-list ap-
15 proach, is available for designers and managers in order to lead to a new aware-
16 ness on the issue and improve the sustainability of construction sites.

17 **Keywords:** construction sites, engineering, environmental management, natural
18 resources, sustainability, water.

19 **1 Introduction**

20 Water is crucial for human life and essential for the life cycle of the Earth, the only
21 living environment for mankind. Several approaches to quantify water consumption
22 by diverse activities have been developed [1], [2]. The Water Footprint is one of the
23 indicators that enables water consumption quantification to produce goods or services
24 [3].

25 Water is subjected to many laws and regulations. However, they do not provide a
26 proper support in quantifying the fair amount of water to be used in a specific human
27 activity so as to avoid unnecessary wastage. The conservation of water in productive
28 processes should be considered as a resource, as this element is a common good to
29 preserve in quality and quantity. The movement towards a sustainable management is
30 fundamental in countries where water resources are already limited or where short-
31 comings have been forecast due to the ongoing process of climate change. [4], [5].

32 The main goal of the present paper was to summarize the state of water manage-
33 ment and consumption within the construction sites. The research here presented fo-
34 cused to the Italian case. The methodology has already been used by the authors in
35 different environmental and occupational contexts [6], [7]. An extract of the main
36 outcomes was summarised in tabular form.

37 2 Materials and Methods

38 In this study, the authors attempted to focus on the presented issue by means of a
 39 recently developed matrix-based analysis [8], [9]. Firstly, the production processes are
 40 divided into phases, sub-phases and elementary stages. Then, focusing on the last, the
 41 used machinery and equipment, the materials (grouped into raw materials, comple-
 42 mentary materials, waste and products), the working environment and the organisa-
 43 tion of the working activities are outlined. Therefore, an exhaustive analysis of all the
 44 different drivers for environmental impacts is implemented: the breakdown structure
 45 of the method allows highlighting the link between water use and its root causes.

46 The types and quality of water used in processes have been classified as follows:

- 47 - Product water: it becomes part of construction materials (e.g. steel, cement or
 48 glass) [10]. It generally does not produce wastes.
- 49 - Process water: includes all the water used in the production processes, which
 50 is then discarded as waste after achieving its function. This is difficult to ac-
 51 count for during the design phase. Treatment methods should be defined for
 52 any site.
- 53 - Service water: it is present on the site to guarantee the necessary sanitary fa-
 54 cilities for the workers; it exits from the site as civil wastewater.

55 3 Results

56 Following the matrix scheme, the use of process, product and service water is showed
 57 for the site cases here taken as examples (Tab. 1). This table shows a good correlation
 58 between the type of water and the application field where it is needed. This correla-
 59 tion is independent of the site typology. Indeed, many potential improvements should
 60 be considered in the process water management, since in this field of application the
 61 water resource do not need very high chemical qualities and there are more chances of
 62 reuse.

63
64

Tab 1. Extract from the water-use table

| Engineering area | Macro-area | Project | Application field | Water type |
|----------------------|------------------------------|-----------------|-------------------|---------------|
| Building engineering | Construction of new building | Residential | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | | | | Product water |
| | | | Work organization | Service water |
| | | | Work environment | Process water |
| | | Service water | | |
| | | Non residential | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | | | | Product water |
| | | | Work organization | Service water |
| Work environment | Process water | | | |
| | Service water | | | |

| | | | | |
|--------------------|--------------------------------|---------------|-------------------|---------------|
| Civil engineering | Construction of linear utility | Roads | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | | | | Product water |
| | | | Work organization | Service water |
| | | | Work environment | Process water |
| | | | | Service water |
| | | Railways | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | | | | Product water |
| | | | Work organization | Service water |
| | | | Work environment | Process water |
| | | | | Service water |
| | | Power-lines | Machinery | Process water |
| | | | | Product water |
| Materials | Process water | | | |
| | Product water | | | |
| | Work organization | Service water | | |
| | Work environment | Process water | | |
| | | Service water | | |
| Water mains | Machinery | Process water | | |
| | | Product water | | |
| | Materials | Process water | | |
| | | Product water | | |
| | Work organization | Service water | | |
| | Work environment | Process water | | |
| | | Service water | | |
| Mining engineering | Underground mining | Soft rock | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | | | | Product water |
| | | | Work organization | Service water |
| | | | Work environment | Process water |
| | | | | Service water |
| | | Hard rock | Machinery | Process water |
| | | | | Product water |
| | | | Materials | Process water |
| | Product water | | | |
| | Work organization | Service water | | |
| | Work environment | Process water | | |
| | | Service water | | |

65 4 Conclusion

66 The results show that, the three kinds of water present on the site are not strictly con-
67 nected to the engineering area involved or the project carried out, but mainly to the
68 application field (machinery, materials, work organization and work environment).
69 For example, materials usually require process water and product water.

70 By knowing the link between water use and its root causes it is possible to design
71 targeted measures to reduce water consumption.

72 This outcome suggests that a common basic water cycle among construction sites
 73 could be identified. This cycle comprises water supplies, methods of purification and
 74 re-injection of water into the environment. Multiple alternatives considering the na-
 75 ture of the area in which the construction site operates, the available resources, the
 76 used machinery and methods could be settled. The model might pave the way for a
 77 renewed regulation in this field for this vital resource. The research activity by the
 78 authors is now proceeding with the development of decision-making tools, such as
 79 checklists, to be proposed to site designers to create a first point of discussion be-
 80 tween the business language and that of environmental safety. This research will be
 81 presented in subsequent works.

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