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REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture

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List of abbreviations

W2R	Water2REturn
WP	Work Package
D	Deliverable
EU	The European Union
EC	European Commission
EASME	European Agency for Small and Medium Enterprises
H2020	Horizon 2020
OH&S	Occupational Health and Safety
PDCA	Plan-Do-Check-Act Approach
APs	Agronomic Products
SBR	Sequencing Batch Reactor

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1. Introduction

1.1 Project summary

Water2REturn proposes a full-scale demonstration process for integrated nutrients recovery from wastewater from the slaughterhouse industry using biochemical and physical technologies and a positive balance in energy footprint. The project will not only produce a nitrate and phosphate concentrate available for use as organic fertiliser in agriculture, but its novelty rests on the use of an innovative fermentative process designed for sludge valorisation which results in a hydrolysed sludge (with a multiplied Biomethane Potential) and bio-stimulants products, with low development costs and high added value in plant nutrition and agriculture [1].

This process is complemented by proven technologies such as biological aeration systems, membrane technologies, anaerobic processes for bio-methane production and algal technologies, all combined in a zero-waste-emission and an integrated monitoring control tool that will improve the quality of data on nutrient flows.

The project will close the loop by demonstrating the benefits associated with nutrients recycling through the implementation of different business models for each final product. This will be done with a systemic and replicable approach that considers economic, governance and social acceptance aspects through the whole chain of water and targets essentially two market demands: 1) Demand for more efficient and sustainable production methods in the meat industry; and 2) Demand for new recycled products as a nutrient source for agriculture. Figure 1 illustrates the closed-loop approach of the Water2Return project in the light of Circular Economy [1].

Figure 1: Water2REturn closed-loop approach in the light of Circular Economy.

1.2 Objectives of WP8

WP8 concerns the environmental, economic, social and risk assessment of the recovery of fertilizers and bio-stimulants from slaughter wastewater.

The objectives of WP8 are:

1. Eco-efficiency assessment by means of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) of fertilizers and bio-stimulants recovery from slaughter wastewater.
2. Sustainability assessment of the Water2REturn system, investigating its social footprint.
3. LCA of the investigated processes and products of the Water2REturn project using primary data from the supply chain actors involved in the project in order to eco-design feedback and optimise the Water2REturn technologies according to the Circular Economy concept.
4. Comparative LCA in order to illustrate the specific advantages of the new technology compared with the traditional technology.
5. Safety, Health and Environment (SHE) evaluation of the Water2REturn technology in order to check and if needed prevent or minimise possible SHE risks.
6. Techno-economic assessment and verification by an external entity of the Water2REturn technologies in order to determine the economic, environmental and commercial feasibility of the proposed process and estimate the cost viability of the overall process within an expected future market.

1.3 Task 8.5: Quantitative risk assessment of potential hazards for humans and environment

Task 8.5 corresponding to the 5th objective of WP8, the SHE evaluation of Water2REturn, has the same duration as the entire project, from month 1 to month 57, and is characterized as described below.

The different occupational health and safety aspects (OH&S) and associated risks for humans in the overall Water2REturn system is evaluated during the execution of this task. This includes mainly biological risks due to the possible, but rare, presence of bacteria during the different processes (risks of pathogens) as well as the risks associated with the use of microalgae and recovery of nutrients from slaughterhouses sewage, health risks related to the emissions and polluted effluents discharged along the process, and all the potential risks associated to the system operation. Besides the OH&S evaluation, recommendations are given to prevent and mitigate bad practices and support the implementation of a safe and healthy workplace through the prevention of work-related injuries and ill-health issues.

The OH&S evaluation is performed according to ISO 45000:2018 on Occupational health and safety management systems. This ISO standard contributes to the following SDG's: 3, 5, 8, 9, 10, 11 and 16. The OH&S issues related to down-stream processing will be carried out directly by the partners involved due to the specific know-how and expertise needed [1].

2. Risk Assessment Methodology

2.1 ISO 45001 Occupational Health and Safety (OH&S) Management System

Occupational Health and Safety (OH&S) management is a day by day concern for every organization, especially when there are legal requirements concerning the safety of production processes involved. ISO 45001:2018 Occupational Health and Safety Management [2] is a standard to support organizations to imbed an OH&S system into the organization, in order not only to secure the health and safety of workers, but to help achieve the bottom line objectives of organizations e.g. to make profit, to produce social responsible and to be effective in production. In general, there is a lot of OH&S know-how present on every level of an organization, whether this is on the work floor where heavy lifting might require safety shoes with steal noses or in the management room where top managers may concern themselves with the question if they are properly in compliance with air emission legislation. But without a proper management system this know-how stays implicit and will not be mobilized in a structured and effective way. It is therefore that ISO 45001:2018 puts the emphasis on the management part of the OH&S issues for organizations. The ISO standard is generic, meaning that it does not give overviews of legislative requirements or strict rules e.g. on whether or not safety shoes are required or obligatory on the work floor. Its intention is also not to appoint an (external) OH&S coordinator or manager that will solely be responsible for taking care of these issues within the organization.

However, its intention is to develop and support an OH&S thinking and attitude within the organization as a whole, supported by an effective management system that is oriented to continual improvement. In order to ensure that hazards, pathways of exposure and risks for workers are identified, documented and communicated, and that proper actions are taken to prevent or mitigate these risks to an acceptable level. In this way it becomes the responsibility of the organization as a whole to ensure the OH&S of all workers. The involvement and support of top management and all other levels in the organization is therefore vital. Continual improvement within the system is implemented in ISO 45001 by adopting the circular Plan-Do-Check-Act (PDCA) approach. This ensures that changes in the organization, legislation, technologies, hazards, risks, prevention and mitigation options and OH&S insights from within and outside the organization are considered in the OH&S management system. Furthermore, frequent audits, internal and external, will check if the management system is still up to date, or if another round in the PCDA cycle is needed on one or more of these issues and if all required procedures and documentation are still in place. The identification, documentation and communication of hazards, pathways of exposure and risks for workers and the evaluation, if and how risks can or should be prevented or mitigated to an acceptable level, are all part of risk assessment. Risk assessment forms one of the starting points for the PDCA approach within a organization, by concretization of the actual risk situation and categorizing these risk according to the necessity of action or safeguarding prevention and mitigation.

2.2 Terms and Definitions

The terms and definitions are described in ISO 45001 [2], and the commonly used terms and definitions in the Task 8.5, are summarized below;

Organization: person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives.

Worker: person performing work or work-related activities that are under the control of the organization.

Workplace: place under the control of the organization where a person needs to be or to go for work purposes.

Legal requirements and other requirements: legal requirements that an organization has to comply with and other requirements that an organization has to or chooses to comply with. (relevant to the OH&S management system)

OH&S management system: management system or part of a management system used to achieve the OH&S policy.

Top management: person or group of people who directs and controls an organization at the highest level.

OH&S policy: policy to prevent work-related injury and ill health to workers and to provide safe and healthy workplaces.

OH&S objective: objective set by the organization to achieve specific results consistent with the OH&S policy.

Hazard: source with a potential to cause injury and ill health.

Risk: effect of uncertainty. Risk is often expressed in terms of a combination of the consequences of an event and the associated “likelihood” of occurrence.

OH&S risk: combination of the likelihood of occurrence of a work-related hazardous event(s) or exposure(s) and the severity of injury and ill health that can be caused by the event(s) or exposure(s).

Incident: occurrence arising out of, or in the course of, work that could or does result in injury and ill health.

Accident: an incident where injury and ill health occurs.

Near-miss: an incident where no injury and ill health occurs, but has the potential to do so.

Injury and ill health: adverse effect on the physical, mental or cognitive condition of a person.

2.3 Plan-Do-Check-Act (PDCA) Approach

The Plan-Do-Check-Act (PDCA) approach is implemented to the entire Water2REturn system in order to provide the continual improvement during the execution of risk assessment.

The PDCA concept is described as an iterative process used by organizations to achieve continual improvement in ISO 45001 [2]. It can be applied to a management system and to each of its individual elements, as follows:

a) **Plan:** determine and assess OH&S risks, OH&S opportunities and other risks and other opportunities, establish OH&S objectives and processes necessary to deliver results in accordance with the organization's OH&S policy;
b) **Do:** implement the processes as planned;
c) **Check:** monitor and measure activities and processes with regard to the OH&S policy and OH&S objectives, and report the results;
d) **Act:** take actions to continually improve the OH&S performance to achieve the intended outcomes.

The standard incorporates the PDCA concept into a new framework, as shown in Figure 2.

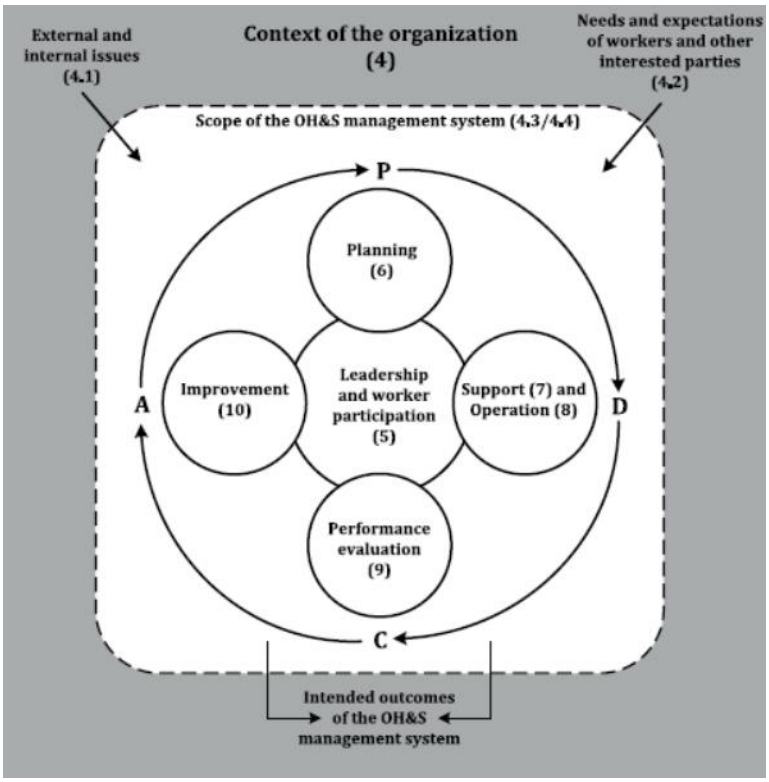

Figure 2: Relationship between PDCA and the framework. The numbers given in brackets refer to the clause numbers in ISO 45001 [2].

2.4 Implementation of the Methodology into Water2REturn

Risk Assessment has been developed along the last decades until becoming a mature subject in the scientific and technical literature [3]. ISO 31000 standard [4] provides a standardized approach of how to assess the risks and the steps for conducting a risk assessment. These steps in accordance with ISO 31000 [4] are summarized in Figure 3. The detailed explanation of the implementation risk assessment process in entire Water2REturn system is given in 'Chapter 3: Risk Assessment Process'.

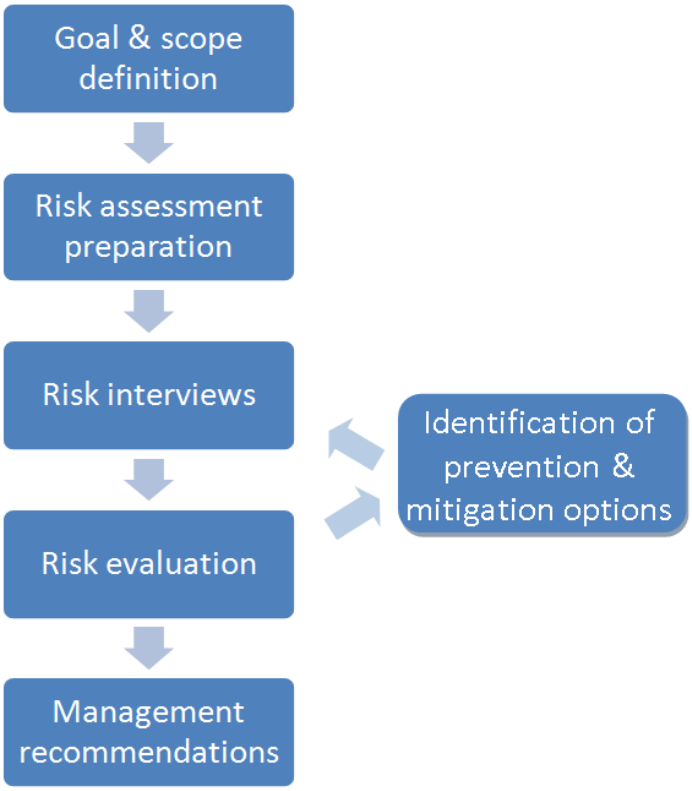

Figure 3: Steps in Risk Assessment.

3. Risk Assessment Process

Risk assessment of Water2REturn system is based on three phases which are start-up, occupational health and safety evaluation (OH&S).

3.1 Phase 1: Start-up

Start-up phase consists of two stages which are 'Goal and scope definition' and 'Risk assessment preparation'.

3.1.1 Goal and scope definition

The goal of task 8.5 is to perform a risk assessment of the Water2REturn system, by means of a risk matrix, which results in a description and quantification where possible of hazards, pathways of exposure, likelihood and derived OH&S risks to workers and interested parties. Furthermore, options to prevent and mitigate these risks are identified. The evaluation of these risk and options are done in accordance with ISO 45001 [2].

In order to establish the defined goal and scope to the Water2REturn system, the system boundaries are determined with consideration of external & internal issues, needs and expectations of workers and other interested parties and planned and/or performed work-related activities.

Definition of system boundaries

Regarding technological system boundaries, the system boundaries as defined in the LCA, LCC and Social LCA of the Water2REturn system are followed, as much as possible with compliance to ISO 45001 [2]. Four production lines (water, sludge, energy and alga lines) are subject to the risk assessment. On the other hand, downstream processes and product safety of products resulting from the Water2REturn system are not taken into account, in accordance with ISO 45001 [2].

ISO 45001:2018 requirements & limitations for the risk assessment

The goal of Task 8.5 is after all not to implement ISO 45001:2018 [2] but only to perform the risk assessment in accordance with this standard. In line with this, not all clauses in the ISO 45001 [2] are followed.

On the other hand, risk assessment is imbedded in the several steps that are performed in a cyclical and repetitive way as implementing two rounds of the PDCA cycle of ISO 45001 [2]. In these two rounds, risk assessment data is collected through interviews and surveys. The first round has an emphasis on determining hazards, pathways of exposure and risks. Subsequently, in the second round, with the input of the insights in these risks, is more focused on determining the prevention and mitigation options. In this way the goal of task 8.5 can be achieved with fulfilling the fundamental requirement of the ISO 45001 [2].

3.1.2 Risk assessment preparation

A desk study is conducted in order to create the working documents in preparation of the risk assessment. Firstly, an interview and survey plan is elaborated. The details for the interviews and surveys are clarified. In line with this, the organization structure of Water2REturn plant is investigated in lines, to identify the content and boundaries of the risk interviews and surveys, as well as the workers and interested parties that are relevant to the OH&S risk assessment. The contact person(s) for each line are selected for the risk interviews and surveys which fulfils the ISO 45001 [2] requirement on the active participation and cooperation of workers into OH&S issues.

As the final step of start-up phase, templates are prepared which are questionnaires and risk matrix. Four different questionnaires are prepared which are customized for each treatment lines (water, sludge, energy and algal lines) & agronomic products (APs) and general organizational aspects in the entire Water2REturn plant. Additionally, a risk matrix format is built up in an excel format to evaluate the risk as a function of severity of a hazard and likelihood of that hazard to happen. A detailed explanation about the risk matrix is given in section 3.2.2.

3.2 Phase 2: Occupational Health & Safety (OH&S) Evaluation

Occupational Health & Safety (OH&S) evaluation phase consists of two stages which are 'First round data collection: Risk interviews and questionnaires' and 'Risk evaluation'.

3.2.1 First round data collection: Risk interviews and questionnaires

The questionnaires are customized for each treatment lines and general organizational aspects in the entire Water2REturn plant, prior to the risk interviews. Totally four questionnaires are prepared for:

- Water line and general organizational aspects
- Sludge line
- Energy line
- Algal line

Risk assessment is an important tool to manage risks in the prevention of undesired effects including work related injury or ill health. It requires a management of the events and continually determination of risks not only for workers, also for the OH&S system. In line with approach, general organizational aspects are taken into consideration during the risk interview and preparation of the questionnaires. Questions which are related general organization are based on the activities in the organization as stated in the questionnaire under the following categories, which are:

- Working conditions such as working hours, shift system
- Human factor including worker profile
- Legislation which describes legal and/or other requirements
- Governance/management which investigates the mechanism to adapt to legal and/or other requirements, such as OH&S management system, OH&S policy, worker participation

On the other hand, the four treatment lines are divided into compartments in line with Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). This division is summarized in Table.1.

Table 1: Compartments for each treatment line in Water2REturn system.

Water line	Sludge line	Energy line	Algae line
• Preliminary treatment • Thickener • Sequencing batch reactor (SBR)	• Sludge concentration: rotary sieve • Sludge storage • Pretreatment • Fermentation	• Equalisation • Anaerobic digester (AD) • Biogas storage • Cogeneration • Tanks (Water and Buffer)	• Inoculation • Main pond • 2-stage sedimenter • Small sedimenter

Content of the questionnaires for the four treatment lines are prepared taking into account the following considerations:

- Routine and non-routine activities
- Noise, vibration, odour, thermal comfort,
- Workplace conditions, such as situation of pedestrian routes, stairs, platforms
- Equipment and chemicals in use
- Waste, emissions, by-products
- Working method, such as shift work, hours of activity, lone working, supervision
- People in the workplace, such as workers, visitors, contractors
- Potential changes in work pattern and / or equipment
- Emergency situations such as fire
- Potential chemical and microbiological hazards
- Potential electrical hazards
- Potential mechanical hazards

Worker participation is an important contribution for the preparation of risk assessment when identifying hazards, elimination or reducing risk by implementation of mitigation or prevention controls in the workplace. This approach has several positive aspects, such as improving safety culture, minimizing risk and embedding best practice, as well as increasing the productivity. In line with this approach, apart from the contact person(s), also the worker at the Water2REturn plant is included to the risk interviews.

The information which has been obtained from risk interviews and questionnaires are registered in an excel file. The risk registration table contains the following information:

- Risk number
- Treatment line

- Unit
- Tasks
- Routine / Non-routine activities
- Identified hazards
- Associated risks
- Potentially affected person(s)
- Risk category
- Risk owner
- Existing mitigation / prevention applications
- Quantification of existing risk
- Suggested mitigation / prevention options
- Quantification of acceptable risk

3.2.2 Risk evaluation

A risk matrix is a semi-quantitative presentation method to represent results from a qualitative risk assessment. It is a function of severity of a hazard and likelihood of that hazard to happen which is calculated by the following formula:

Risk = Severity X Likelihood

The risk matrix (5x5) is built up in an excel format which has on the x-axis the level of severity of a hazard and on the y-axis the level of the likelihood of such hazard to happen. The level of severity of a hazard and their likelihoods are divided into five specific categories and quantified by given a number between 1 to 5 which indicates very low to very high, respectively.

Severity of a hazard is measured on a 5-point scale:

- **1 = Insignificant** – No injury / minor injuries with first aid / no work loss occur.
- **2 = Significant** – Minor injuries, no work loss occurs.
- **3 = Severe** – Minor injuries, short-term treatment requires.
- **4 = Major** – Major injuries / permanent disability occurs.
- **5 = Catastrophic** – Fatal injuries / permanent disability occurs.

Likelihood of a hazard to happen is measured on a 5-point scale:

- **1 = Rare** – It is extremely unlikely that the incident will occur.
- **2 = Unlikely** – It is unlikely to occur.
- **3 = Possible** – It is a likely event.
- **4 = Probable** – It is very likely to occur.
- **5 = Certain** – It will happen in the close future.

The risk is indicated as a colour code such as traffic light system: green, yellow and red. An example of a risk matrix is given in Figure 4 [3].

The risk matrix can be interpreted as follows:

- **Low risks (green)** – The risk here is low, so risks can usually be accepted. Risk avoidance or mitigation actions are likely not necessary.
- **Medium risks (yellow)** – The risk here is medium, so you should consider risk mitigation actions to reduce or resolve the consequences.
- **High risks (red)** – These are exceptionally high risks, so adopting a strategy that eradicates them, such as risk avoidance, is a likely course of action.

Figure 4: Example risk matrix [3].

Additionally, risks are listed under four risk categories. This categorization helps us in the second round to understand the root causes of the risks and where the actions are needed to be taken for the elimination/mitigation. The risk categories are listed as follows:

i. Technology,
ii. Human factor,
iii. Legislation,
iv. Governance / management.

3.3 Phase 3: Occupational Health & Safety (OH&S) Options and Recommendations

Occupational Health & Safety (OH&S) options and recommendations phase consists of two stages which are 'Second round data collection: Identification of necessary prevention and mitigation options and Management recommendations.

3.3.1 Second round data collection: Identification of necessary prevention and mitigation options

General principles for risk prevention

The organization shall establish, implement and maintain a process for the elimination of hazards and reduction of OH&S risks using the hierarchy of controls. Hierarchy of controls are summarized in ISO 45001 [2] as follows:

i. Elimination
ii. Substitution
iii. Engineering Controls
iv. Administrative Controls
v. Personal protective equipment (PPE)

The hierarchy of control is a step-by-step process for controlling risks in the workplace. According to this hierarchy, eliminating the risk provides the most effective level of control, while reducing the risk through the use of protective personal equipment (PPE) is the least effective level of control.

NIOSH [5] has represented the structure of hierarchy of controls as a triangle with a apex upwards showing the priority of actions and decreasing effectiveness from top to the bottom (Figure 5).

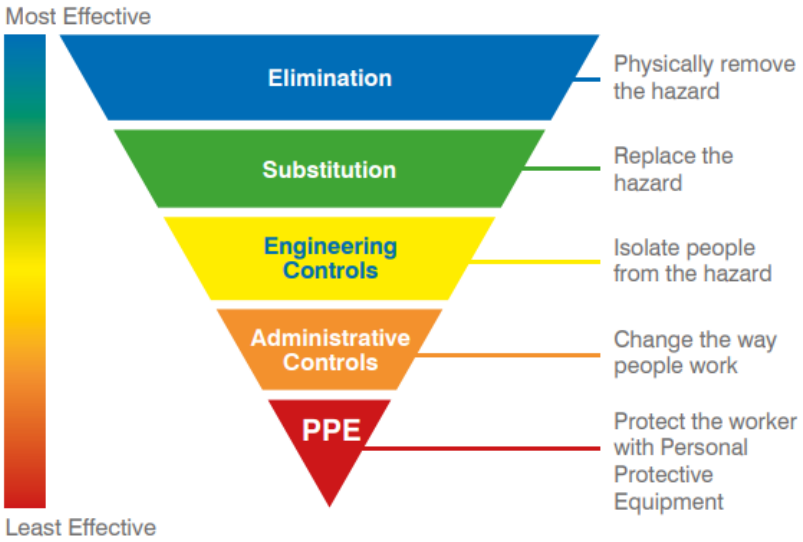

Figure 5. Hierarchy of control options [5]

Elimination: Eliminating the risk is the effective control option among all hierarchy of controls options. It aims to eliminate origin of the hazard which can cause a risk in the workplace. In this way, the risks posed by the system can be eliminated by removing the hazard completely. For instance, removing an equipment in the workplace which can cause a hazard, eliminates the risks it creates. This risk prevention option can be applicable at every stage of a system. Particularly, it can be easier and cheaper if it is considered during the design or planning stage of a project or product.

Substitution: Substitution is applied to a system when the elimination of hazards and risks are not applicable. In this option, the risks posed by a system can be eliminated by replacing it by a less hazardous process, considering its conditions of use. It is based on substitution of the hazard with a safer alternative.

Engineering Controls: Engineering controls aim to create a barrier between the worker and the hazard. The main difference in this control method is the application of the method on the source of the hazard instead of potentially affected people at the workplace. Engineering control methods can be summarized as follows:

- redesigning, changing, or substituting equipment
- isolating workers from the hazard
- enclosing of hazard
- establishing barriers when enclosing is not possible
- implementing automation instead of human work

Administrative Controls: Administrative controls focus on changing people's behaviour instead of eliminate the existing hazard. These control methods include conducting trainings, developing procedures and policies, using OH&S signs or rearranging shifts to reduce the exposure time in order to diminish the threat of a hazard to potentially affected people.

Personal protective equipment (PPE): PPE is a last desirable control measure. They can be used as a supplemental option to support higher levels of exposure control. PPE may include respiratory protection devices, dermal protection and eye protection such as helmet, face masks, respirators, gloves, boots, goggles, ear-muffs and reflecting clothing.

Besides being the least effective control methods, there are significant points before employing this option at the workplace. PPE should only be used under certain circumstances:

- when no other control method is possible
- in addition to other controls being installed or implemented
- for non-routine activities such as emergencies and maintenance
- where the first four control methods cannot be applicable and/or are not sufficient

3.3.2 Management recommendations

Risk assessment is concluded by presenting management recommendations for each step of the PDCA circle, in conformity with ISO 45001:2018. These recommendations should be given regarding the risks that are identified, but also regarding possible blank spots due to uncertainty or lacking data in the risk assessment that in future may need attention. Some of the relevant management recommendations are summarized as follows:

- The organization should establish an Occupational Health & Safety (OH&S) management system and define the responsible person(s).
- The organization should determine the legal and other requirements that are related to organization's hazards, OH&S risks and OH&S management system, such as risk assessment, OH&S trainings of workers, voluntary implementation of ISO 45001.
- The organization should develop an OH&S policy with the relevant objectives to help meet the requirements. OH&S Policy should documented and communicated with workers.
- A monitoring mechanism should be established for implementation and maintenance of OH&S policy and management system, such as internal audit system.
- The organization should develop a documentation system on OH&S management, including preparing procedures for each tasks and keeping the record of controls, analysis, trainings.
- The top management involved to the OH&S activities including awareness, responsiveness, active support and feedback, such as internal audits, incident investigation, participation to emergency trainings, participation to annual OH&S week/activities.
- The organizational roles, responsibilities and authorities which are related OH&S should be determined, documented and communicated with workers.
- A method should be established for consultation and participation of workers on OH&S issues, including selection of worker representative(s), replacing suggestion and near-miss communication boxes in the workplace and holding annual OH&S week/activities.
- The organization should embed the risk management system and its policy into the OH&S management system.

4 Results

Water2REturn system has been evaluated in two steps: general management aspects, four treatment lines and the agronomic products (APs) which are obtained from the outputs of the Water2REturn plant. OH&S risk evaluation has been elaborated by means of a risk matrix [6].

Specifically, risks have been categorized under six sections:

i. general management aspects
ii. water line
iii. sludge line
iv. energy line
v. algae line
vi. APs production

4.1 General management aspects

Under this section, the management of the Water2REturn plant has been evaluated in terms of the organization of the activities. In line with this, working hours, human factor, legislation, governance and management of the sub-categories were investigated in order to define worker profile, exiting situation on consultation and participation of workers, legal requirements, organizational roles, responsibilities and authorities.

Three potential hazards were detected and associated risks were calculated as low risks for the general management aspects section. These risks are grouped under governance and management and legislation risk categories.

Despite of having only low risks in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied resulting in even more lower risks. Suggested risk prevention and mitigation options for the general management aspects are:

- ✓ Creating the forms for communication of the near-miss and suggestions and locating boxes at the plant for collecting these communications
- ✓ Providing an easily visible copy of summary of the OH&S policy at the plant
- ✓ Executing emergency preparedness trainings once a year

4.2 Water line

The Water line has been investigated in three main compartments, which are:

- Preliminary treatment
- Thickener
- Sequencing batch reactor (SBR)

During the risk assessment process, routine & non-routine activities, work place conditions, equipment in use, materials & substances in use, waste & emissions & by-products obtained, working method, access to workplace, potential & planned changes and potential & actual incidents have been examined.

Thirty-two potential hazards have been detected and associated risks were calculated as 25 low and 7 medium risks for the water line section. These risks are grouped under human factor, governance and management and technology risk categories.

The highest number of risks have been detected in the water line. It can be considered as an expected result due to the potential contact with raw slaughterhouse wastewater which might be higher in this treatment line. Additionally, number of equipments, including tanks with confined space are other factors which are affecting the number of identified hazards and associated risks.

Despite of having only low risks that are dominant in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied on both low & medium risks and final risks have been calculated being low risks for all 32 risks. Suggested risk prevention and mitigation options for the water line are:

- ✓ Preparing daily, weekly and monthly lists for the routine activities to be prepared better for any unexpected immediate actions
- ✓ Attending to the annual OH&S training to increase the awareness on the usage of PPE, potential chemical & biological hazards, ergonomical hazards and moving & handling objects
- ✓ Controlling safety switch & emergency stop periodically and keeping the control records
- ✓ Controlling pressure safety valve periodically and keeping the control records
- ✓ Providing an easily visible operating procedure close to the equipment
- ✓ Executing a written entry permit system and providing an attendant for continuously motinoring during the task
- ✓ Controlling platforms and stairs periodically and keeping the control records
- ✓ Identifying the wet floors with a sign after cleaning
- ✓ Controlling the situation of foaming in SBR periodically and limit the access of the pedestrians to the surrending areas which might be potentially affected in case of excessive foaming
- ✓ Controlling the material safety data sheets (MSDS) forms periodically and replacing them with new ones in case of any changes of the purchased chemical and/or any damage on the forms
- ✓ Preparing a list and a map which indicates the location of the fire extinguisher at the plant and keeping the controls under record

- ✓ Using the appropriate PPE, such as:
  - Earplugs: in case of exposure to noise hazard
  - Helmet: in case of risk of head bumping
  - Gloves and safety googles: in case of contact chemicals and/or substances with biological hazard, i.e raw slaughterhouse wastewater
  - Water&slip-resistance safety footwear: in case of work on the wet floors

4.3 Sludge line

The Sludge line was investigated in four main compartments, which are:

- Sludge concentration: rotary sieve
- Sludge storage
- Pre-treatment
- Fermentation

During the risk assessment process, routine & non-routine activities, work place conditions, equipment in use, materials & substances in use, waste & emissions & by-products obtained, working method, access to workplace, potential & planned changes and potential & actual incidents have been examined.

Twenty-five potential hazards have been detected and associated risks have been calculated as 21 low and 4 medium risks for the sludge line section These risks are grouped under human factor, governance and management and technology risk categories.

Despite of having only low risks tha are dominant in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied on both low & medium risks and final risks have been calculated being low risks for all 25 risks. Suggested risk prevention and mitigation options for the sludge line are:

- ✓ Controlling the function of safety switch & emergency stop periaodically and keeping the control records
- ✓ Controlling platforms and stairs periodically and keeping the control records
- ✓ Attending to the annual OH&S training to increase the awareness on the usage of PPE and potential chemical & biological hazards, ergonomical hazards and moving & handling objects
- ✓ Following the manufacturer's operating instructions during the opeartion of the machine
- ✓ Providing an easily visible operating procedure close to the equipment and keeping the periodical control records
- ✓ Preparing a list and a map which indicates the location of the fire extinguisher at the plant and keeping the controls under record
- ✓ Labelling all chemical containers and controlling the material safety data sheets (MSDS) forms periodically and replacing them with new ones in case of any changes of the purchased chemical and/or any damage on the forms
- ✓ Identifying the wet floors after cleaning with a sign

- ✓ Using the appropriate PPE, such as:
  - Earplugs: in case of exposure to noise hazard
  - Heat-reflective clothing: in case of exposure to heat

4.4 Energy line

The Energy line has been investigated in five main compartments, which are:

- Equalisation
- Anaerobic digester (AD)
- Biogas storage
- Cogeneration
- Tanks (Water and Buffer tanks)

During the risk assessment process, routine & non-routine activities, work place conditions, equipment in use, materials & substances in use, waste & emissions& by-products obtained, working method, access to workplace, potential & planned changes and potential & actual incidents have been examined.

Fifteen potential hazards have been detected and associated risks have been calculated being 13 low and 2 medium risks for the energy line section. These risks are grouped under human factor, governance and management and technology risk categories.

Despite of having only 2 medium risks in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied on both low & medium risks and final risks have been calculated being low risks for all 15 risks. Suggested risk prevention and mitigation options for the energy line are:

- ✓ Attending to the annual OH&S training to increase the awareness on the usage of PPE and potential chemical & biological hazards, ergonomical hazards and moving & handling objects
- ✓ Documenting the periodic controls and calibrations. Providing professional calibration service for mechanical protection device and flame arrester
- ✓ Identifying the wet floors / working area for the repairment with a sign
- ✓ Controlling over pressure valve periodically and keeping the control reports
- ✓ Conducting periodical air quality measurements for the cogeneration unit
- ✓ Preparing a list and a map which indicates the location of the fire extinguisher at the plant and keeping the controls under record
- ✓ Controlling the material safety data sheets (MSDS) forms periodically and replacing them with new ones in case of any changes of the purchased chemical and/or any damage on the forms

4.5 Algae line

The Algae line has been investigated in four main compartments, which are:

- Inoculation
- Main pond
- 2-stage sedimenter
- Small sedimenter

During the risk assessment process, routine & non-routine activities, work place conditions, equipment in use, materials & substances in use, waste & emissions & by-products obtained, working method, access to workplace, potential & planned changes and potential & actual incidents have been examined.

Sixteen potential hazards have been detected and associated risks have been calculated being 10 low and 6 medium risks for the algae line section. These risks are grouped under human factor, governance and management and technology risk categories.

Despite of having only low risks that are dominant in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied on both low & medium risks and final risks have been calculated being low risks for all 16 risks. Suggested risk prevention and mitigation options for the algae line are:

- ✓ Attending to the annual OH&S training to increase the awareness on the usage of PPE and potential chemical & biological hazards, ergonomical hazards and moving & handling objects
- ✓ Installing a safety switch & emergency stop to the equipment with rotating parts
- ✓ Following the weather forecast daily to prevent any overflow from the ponds in case of excessive rain
- ✓ Consolidating the vehichle road to transport the IBC tank etc., for collecting the harvested algal biomass
- ✓ Controlling the material safety data sheets (MSDS) forms periodically and replacing them with new ones in case of any changes of the purchased chemical and/or any damage on the forms
- ✓ Identifying the wet floors after cleaning with a sign
- ✓ Using the appropriate PPE, such as water&slip-resistance safety footwear in case of work on the wet floors

4.6 Agronomic products (APs)

Agronomic products (APs) which are obtained from outputs of the Water2REturn system have been investigated as the final part of the risk assessment. During the risk assessment process, production of APs and users of APs have been examined. Four potential hazards have been detected and associated risks have been calculated being 3 low and 1 medium risks for the agronomic products (APs) section. These risks are grouped under human factor, governance and management and technology risk categories.

Despite of having only one medium risk detected in this section, for the continual improvement in line with ISO 45001 [2], risk prevention and mitigation have been applied on both low & medium risks and final risks have been calculated being low risks for all 4 risks. Suggested risk prevention and mitigation options for the agronomic products (APs) section are:

- ✓ Attending to the annual OH&S training to increase the awareness on the usage of PPE and potential biological hazards
- ✓ Executing voluntarily a risk assessment for health & safety and environmental exposure of the products
- ✓ Providing a report (D7.2), including dossier on how the product can optimize/create maximum contribution to the health and safety of the user and recommendations for use

5 Conclusions

The OH&S evaluation of Water2REturn system has been performed according to ISO 45000:2018 on Occupational health and safety management systems [2]. The system was evaluated in six parts; general management aspects, four treatment lines and the agronomic products (APs) which are obtained from the outputs of the demonstration plant.

Risk assessment process has been conducted in two rounds; the first round mainly consists of identifying the potential hazards and evaluation of associated risks while second round focused on suggestions of prevention & mitigation options for the risks which obtained from the first round, as well as management recommendations.

Totally, 95 hazards have been identified and the associated risks calculated in the risk matrix of the Water2REturn system [6]; 71 of these risks have been identified as caused by the routine activities, while the rest, 10 of the risks might be occurred during the execution of the non-routine activities in the Water2REturn system. The remaining 14 risk have been detected for both cases; during carrying out routine and non-routine activities.

Twenty of the risks are medium risks while the remaining risks are elaborated as low risks. High risk is not detected in the Water2REturn system. Risk prevention & mitigation options have been applied in order to reduce the medium risks into low risks and to improve the existing situation for low risks. After application of risk prevention & mitigation options, the risk has been recalculated being all low risks.

The highest number of risks have been detected in the water line (32 risks). It can be considered as an expected result due to the potential contact with raw slaughterhouse wastewater which might be higher in this treatment line. Additionally, number of equipments, including tanks with confined space are other factors which are affecting the number of identified hazards and associated risks. This treatment line is followed by the sludge line (25 risks), the algae line (16 risks), the energy line (15 risks), agronomic products (APs) (4 risks) and general management aspects (3 risks), respectively.

In addition to the risk level, the risk category was investigated during the risk assessment process. The biggest proportion of the risks are grouped under ‘human factor’ (54 risks) risk category. This risk category is followed by ‘technology’ (24 risks), ‘governance / management’ (16 risks) and ‘legislation’ (1 risk), respectively.

In order to finalize ‘D8.3 Report on occupational health & safety’, conclusions are drawn from the different phases and formulated as recommendations for each step of the PDCA circle, in conformity with ISO 45001:2018 [2]. These recommendations concern the risks and risks options that have been identified, but also possible blank spots due to uncertainty or lacking data in the risk assessment that in future may need attention. Also findings and recommendations have been presented regarding the process of risk data collection, communication and other processes that may be relevant for the OH&S continual improvement and OH&S performance of the Water2REturn system.

In line with this perspective which has been explained above, the following management recommendations are provided for the continual improvement of OH&S management of the Water2REturn system:

- The involvement of the workers themselves is an important factor in the success of OH&S management system at the workplace. Participation of workers on OH&S issues at workplace should be increased by creating the forms for communication of the near-miss & suggestions and locating boxes at the plant for collecting these communications.
- The controlling records/reports which are related to periodic controls of the equipments, including fire extinguishers, have to be documented.
- A written entry permit system should be executed for the works in a confined space.
- Chemicals have to be labelled and kept only at the chemical storage area with their material safety data sheets (MSDS) where the instructions for the safe use and potential hazards associated with the chemicals are written on it.
- An easily visible and readable operating procedure must be provided at the workplace for the equipments.
- Attandence of workers to the annual OH&S training should be followed and ensured to increase the awareness on the correct usage of PPE, potential chemical, biological and ergonomic hazards, as well as executing emergency preparedness trainings.

6 References

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[2] ISO 2018 ISO 45001: Occupational health and safety management systems - Requirements with guidance for use. ISO 45001:2018 (https://www.iso.org/standard/63787.html)

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[4] ISO/IEC 2019 ISO 31010: Risk management — Principles and Guidelines. International Standards Organisation (ISO/IEC), ISO 31010:2019 (https://www.iso.org/standard/72140.html)

[5] The National Institute for Occupational Safety and Health (NIOSH) (https://www.cdc.gov/niosh/topics/hierarchy/default.html)

[6] 2B S.r.l. (2022). Risk matrix of the Water2REturn system.