# SUSTAINABLE PATHWAYS FOR LIQUID WASTE MANAGEMENT[1]

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**Abstract**

In the Pavia area of the Po valley, traditionally devoted to rice growing, optimisation of water treatment is a fundamental objective. The challenge consists in implementing sustainable processes that comply with the directives of EU policy for the valorisation of materials and energy from waste.

This paper presents integrated management hypothesis that can transform liquid waste into a resource. The analysis of the technologies, used for the treatment, aims at identifying pathways for water valorisation, through their reuse, and pathways for the use of spreadable sludge with high organic load, in order to combat the desertification. Nevertheless, the preservation of the chemical and physical properties for the recipient water bodies must not be neglected.

**Riassunto**

Nel tratto pavese della pianura Padana, tradizionalmente vocato alla risicoltura, l'ottimizzazione del trattamento delle acque risulta un obiettivo imprescindibile. Oggi, la sfida consiste nell'implementazione di processi sostenibili, nel rispetto delle indicazioni di politica comunitaria di valorizzazione di materia ed energia dai rifiuti.

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Il lavoro presenta, dunque, ipotesi di gestione integrata che facciano del rifiuto liquido una risorsa. L'analisi delle tecnologie, utilizzate per il trattamento, mira ad individuare i percorsi di valorizzazione delle acque, attraverso il loro il riuso, e di impiego delle frazioni palabili ad elevato carico organico, per contrastare la desertificazione, senza trascurare la conservazione delle qualità chimico fisiche dei corpi idrici ricettori.

**Keywords**: Liquid waste management, sludge spreading, industrial wastewater.

## Introduction

The interaction of human existence with water generates an inevitable modification that will become more significant when anthropic activities increase their complexity. In the present context, the concept of sustainable development in relation to water resources implies the implementation of technologies increasingly geared towards the minimisation of human impact for water management (1).

The full accomplishment of this objective can be reached only by means of synergic measures acting on the withdrawal and utilisation phases and up to the reintroduction of wastewater in the environment. This paper is focused on this last phase of the cycle, examining the technologies implemented at two facilities operating in the Pavia province (Italy). Their objective is the optimisation of, respectively, industrial wastewater management in a sensitive environmental context, and the efficiency of sludge treatment destined for agricultural spreading. The role of water in the Pavia province becomes all the time more fundamental and strategic when considering the large part played by rice growing in the local economy: out of the total rice growing surface in Europe, more than 56% is located in Italy and, of this, 35% (data from Ente Nazionale Risi, 2006) is to be found in the Pavia province.

## The treatment of industrial wasterwater in a sensitive area

The ISO 9001 certified facility examined is situated close to Pavia in an area with high farming vocation. It was created at the beginning of the 90's for urban wastewater treatment with a capacity of 12,500 pe (person equivalent).

A second line was added in 2006 for the treatment of industrial wastewater that are composed by 80% of landfill and composting leachate (code CER 190703) and characterised by a significantly greater polluting load than urban wastewater.

The potential treatment capacity of this line is equal to 200 $m^3$/day and the average treatment is of 100 $m^3$/day corresponding to approximately 8% of the total amount treated at the facility.

It is interesting to evaluate which are the environmental benefits generated given the particularity of the receiving water body whose waters, during the period of irrigation in agriculture, are discharged into a basin that becomes a zone of fish restocking for cyprinid species with complete fishing interdiction.

Thus, the receiving water body is a sensitive reality, and for sustainability purposes, becomes particularly relevant the efficiency of pollutants abatement by the purification plant.

At this point, emerges a first element of compatibility regarding managerial choices related to the destination of materials removed from wastewater, by means of a first mechanical treatment, that are conveyed to incineration plants with energy recovery.

Wastewaters with the greater pollutant load go through a specific chemical-physical process aimed at abating metals present in the liquid by using reagents that allow the return to the solid state (floccules) of substances previously in solution.

Wastewater and the floccules contained inside pass to the primary settler, where sludge is decanted at the tub bottom while the supernatant water is conveyed towards biological treatment (2), where also converge wastewaters with minor pollutant load.

The biological treatment of this line is characterised by a particularly efficient aeration system that guarantees a homogeneous oxidation within the tub, with automatic monitoring of the level of dissolved oxygen, by means of an inserted probe.

Sludge present at the bottom of the settlers in this line, after being pumped to a thickener, are conveyed to specific plants for the treatment of chemical sludge given its high concentration of pollutants. Moreover, it must be pointed out that the output waters from this treatment line are not directly discharged in a receptor water body, but are returned upstream in the plant, within the line designed for the treatment of urban wastewater and are therefore submitted to a second purification process, as shown in Fig. 1.

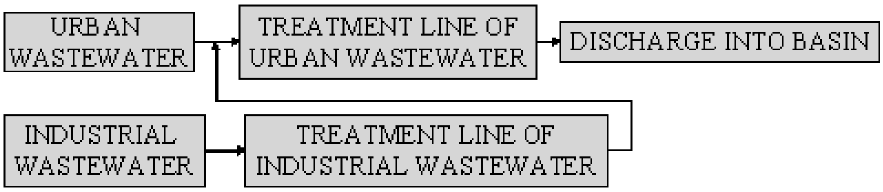


*Fig. 1* – Schematic representation of the plant

Therefore, in this case the evaluation of compatibility for the activated technological cycles with respect to standards limits, imposed as assurance of the facility efficiency and thus of water protection, should take into account the emission limits imposed for sewerage.

Table 1 confirms the full compliance of expected limits for sewerage discharge, although the most interesting aspect emerges by comparing the values obtained downstream of the line, that even possessing an elevated pollutant load, comply essentially with the values established for discharge in surface waters.

This is certainly an encouraging element of the purification efficiency obtained by the process.

TABLE 1

**DAILY ANALYSIS OF THE MAIN MONITORED PARAMETERS (VALUES DIFFERENT FROM PH- EXPRESSED IN mg/L)**

| Element | Output line of industrial waste treatment | Limits for sewerage discharge[1] | Limits for discharge in surface water[1] |
|---|---|---|---|
| pH | 7.71 | 5.5 - 9.5 | 5.5 - 9.5 |
| COD | 157 | ≤ 500 | ≤ 160 |
| $NH_4$ | Nr | ≤ 30 | ≤ 15 |
| $NO_3$ | 12.4 | ≤ 30 | ≤ 20 |
| $NO_2$ | 0.035 | ≤ 0.6 | ≤ 0.6 |
| Cl- | 1134 | ≤ 1200 | ≤ 1200 |
| P | 1.2 | ≤ 10 | ≤ 10 |

[1] D.Lgs 152/06 - Parte terza, Allegato 5, Tabella 3

To evaluate the water quality of the receptor water body situated upstream of the discharge, the reference considered was the “Plan for the protection and use of waters” that, regarding the presence of chemical elements within water streams, considers in particular phosphorous, ammonia and COD concentrations. Given the complete absence of phosphorous and ammonia within the stream and considering the chemical analysis, it can be concluded that the upstream receptor basin presents good conditions for what concerns the concentration of chemical elements present.

It is important to point out that the values obtained from test performed in the facility are linked to the characteristics of the input urban wastewaters, deriving from an area with high farming vocation and composed of small human settlements.

The values obtained from analysis performed on a sample taken downstream of the discharge, have allowed a comparison whose values are shown in Table 2. This table shows evidence of a reduction in the concentration levels of B, K, Mo, S and Se that are no longer detectable downstream. It is assumed that this is due to a dilution phenomenon that for the case under study becomes significant as a function of the ratio between the flow rate of the discharge and that of the receptor basin (the value is in the range from one to a few tenths). The concentrations of Be, Co, Cr, Na, Ni, and V remain constant; Mg and Ca undergo a small increase in concentration while the pH, conductivity and chlorides show a percentage increment comprised between 3 and 7.

TABLE 2

**COMPARISON BETWEEN CONCENTRATIONS IN THE RECEPTOR BASIN UPSTREAM AND DOWNSTREAM OF THE DISCHARGE**

| **Element** | **Variation %** |
|---|---|
| Al | not significant |
| B | − 9.80 |
| Ba | not significant |
| Be | constant |
| Ca | +1.2 |
| Co | constant |
| Cr | constant |
| K | −3.34 |
| Mg | +1.57 |
| Mo | − 15.79 |
| Na | constant |

| **Element** | **Variation %** |
|---|---|
| Ni | constant |
| S | − 3.10 |
| Se | not detected |
| Sn | +1.51 |
| V | constant |
| NO2 | − 14.28 |
| NO3 | +97.67 |
| Cl- | +4.68 |
| COD | +111 |
| Total surfactants | +37.04 |
| pH | +3.23 |
| Conducivity | +6.51 |

Amongst the monitored parameters, those that show a significant increase of concentration downstream of the discharge are: $NO_3$, total surfactants and COD. Nevertheless, Fig. 2 proves that also these latest parameters are largely below the legal limits.

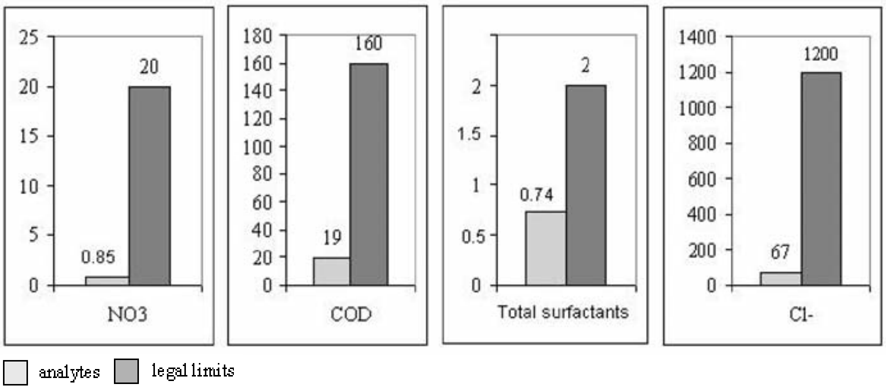


*Fig. 2* – Comparison between analytes concentration and the respective legal limits (values expressed in mg/L).

Furthermore, it is worth considering that thanks to the efficiency of the chemical-physical treatment, the discharge does not contain heavy metals and that the biological purification process avoids the presence of phosphorous in the surface water body.

Considering the fact that the facility under study works in cost-effective conditions and that the plant efficiency has been compatible with the objective of territorial conservation, it can be avowed that it represents an example of sustainability by harmonising human activity with the protection of sensitive areas.

## Sludge treatment for agricultural application

The percentage of the whole organic matter contained in treated sludge that is used in agriculture equals 36%[2]. This process allows exploiting the commodity assets of some types of organic sludge (3) that can be spread on soil, after appropriate sanitation treatment, thus limiting the use of fertilizers or chemical nourishment (4).

[2] The detection of the remaining 64%, shows that 46% is conveyed to landfills, 15% is used for construction sludge mixed with other materials for particular productions, 3% is taken to incineration with or without energy recovery. It is still open a sustainability evaluation for the single processes.

Spreading sludge on grounds causes a definite increase of microbial population and a proliferation of microbiological processes of soils. However, since also pathogenic micro-organisms are present, controlled spreading requires sanitation processes that avoid adverse health effects.

To avoid risks for the environmental and for humans, the agronomic use of sludge complying with current legislation (DLgs 152/06) has to rely on soils analysis[3]. In particular, the issue of managing heavy metals is strictly correlated to the characteristics of treated grounds, since immobilisation or mobility of such metals are linked to the internal chemical-physical characteristics of the soil.

The facility examined, always in the Pavia province, operates since 1991, it is certified ISO 9001, ISO 14001, registered EMAS and authorised to treat 150,000 tons/year that in the three years from 2005 to 2007, where as an average composed by more than 96% of sludge derived from biological purification plants for water[4]. The facility has the objective of returning to the agricultural sector the fertilising elements contained in biological sludge, thus minimising undesirable aspects and assuring respect for environment and quality.

An experiment carried out during the summer of 2008, had the objective of identifying possible pathways that, while improving efficiency within the facility, allow the treatment of a larger amount of sludge targeted towards the control of undesirable microbial flora for controlled spreading in agriculture.

For this purpose, it was examined the variation of pathogenic micro-organisms present within a sample of sludge withdrawn at the pulper output, as a function of pH value and of the residence time elapsed from the time of withdrawal.

[3] Other problematic elements are the persistent organic substances, which are affected by the degradative capacity of the microflora present on soils.

[4] The remaining waste treated belong to the following types: waste from agro-food industry (as average more than 2% during the three years 2005-2007) salt solutions similar to fertilizers on the market (as average less than 1% during the three years 2005-2007)

TABLE 3

**MICROBIOLOGICAL ANALYSIS OF FAECAL COLIFORMS AS A FUNCTION OF PH INCREASE (VALUES EXPRESSED IN CFU[5]/g MEASURED ON RAW SAMPLES)**

| Consignment date | pH | Analysis result 1 week later |
|---|---|---|
| 17/07/2008 | 8.75 | <10 |
| 18/07/2008 | 8.89 | 1200 |
| 07/07/2008 | 9 | <10 |
| 22/07/2008 | 9.01 | 24 |
| 29/07/2008 | 9.07 | 24000 |
| 31/07/2008 | 9.09 | 390 |
| 09/07/2008 | 9.14 | <10 |
| 10/07/2008 | 9.16 | <10 |
| 16/07/2008 | 9.16 | <10 |
| 25/07/2008 | 9.18 | <10 |
| 15/07/2008 | 9.21 | <10 |
| 02/07/2008 | 9.25 | <10 |
| 26/07/2008 | 9.27 | 606 |
| 23/07/2008 | 9.27 | <10 |
| 01/07/2008 | 9.3 | <10 |
| 24/07/2008 | 9.32 | <10 |
| 30/07/2008 | 9.48 | <10 |
| 03/07/2008 | 9.6 | <10 |
| 04/07/2008 | 9.76 | <10 |

The results reported in Table 3, show that the samples having lowest pH values at their withdrawal are those that, a week later, laboratory analysis still reveal the presence of faecal coliforms.

Although, still remaining well below the legal limits expected for sludge spreading, these values highlight the fact that the pH dosage phase at the pulper (by adding variable amounts of ammonia) represents a critical moment of the whole process of sludge management.

Examining the other fundamental variable, i.e. the residence time of sludge within the treatment plants, it was particularly important to optimise this time in the facility that currently equals approximately 10 days[6].

With the exception of only one value, probably due to an initially anomalous sample, the experiment has evidenced that this timing is mostly precautionary since the dosage shows that after seven days all the values are widely below legal limits (10.000 MPN /grams of dry substance).

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5 CFU - Colonies forming unit

6 Current sector literature agrees that for pH values ≥ 9, at room temperature (20° ÷ 25° C), the lifetime oh these pathogens is reduced to values comprised between 0 and 6%, within the first 15 days of treatment.

In particular for pH values comprised between 9.1 e 9.8, the faecal coliforms values are lower than 10 UFC/g (measured on raw samples).
To conclude, it can be asserted that the data emerged show the possibility of improving the plant efficiency by reducing the residence time, increasing potential treatment capacity in order to achieve economies of scale in a framework of environmental compatibility.

The ever increasing amount of sludge produced and the potential improvement of treatment are in conflict with the restrictions imposed on sludge spreading by the Nitrate Directive (DIR 91/676/CEE) highlight a critical point that can be overcome by an integrated strategy of the supply chain supported by appropriate regulation and standards adjustments (5).

## Conclusions

In the predominantly farming context of the Pavia province, the two cases examined of industrial wastewater treatment and of undesirable microbial flora control for sludge management, represent an example of sustainable pathways even in sensitive areas with a natural rice-growing vocation of the local agriculture.

The level of compatibility achieved by means of the plant technology available results quite interesting for the treatment of wastewater with a high pollutant load also in contexts with natural valence, which highlights the possibility of harmonising human development with territorial development conditions.

In view of EU principles that advise materials recovery from waste, controlled spreading appears to be a particularly interesting path for sludge derived from wastewater treatment.

Sludge treated in this way represents a valid example of waste that can become a resource for the agricultural sector, if subjected to an adequate technological cycle.

Being convinced that the latter represents the most delicate phase of the whole management cycle for wastewaters given its potential environmental effects, it would be desirable to outline a revision of the Nitrate Directive as it has already occurred in the Flanders region. This has been oriented towards an authorised treatment of the sludge solid phase, in facilities devoted to the production of natural fertilisers to be marketed also outside their collection basin.

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