Case study of full scale treatment plant for wastewater from train washing system

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Abstract
Due to the continuous growth of the world population, development of agriculture and industry in the emerging countries as well as climate change, the insufficiency of water has become in the past few years an increasingly important issue. Increasing water consumption causes enormous challenges to water infrastructure planning. Conventional wastewater management is based on high-priced drain systems and large wastewater treatment plants. Nowadays the purpose of the research is directed towards saving and reutilization of wastewater and energy. The aim of this paper was to study a full scale treatment plant for wastewater from train washing system in terms of performance, effluent reuse, treatment efficiencies (BOD, COD, TSS removal), operation and maintenance costs. A process data collection was performed and integrated with a characterization of the process effluents in terms of treatability and reusability. In order to evaluate properly the wastewater loading, an analysis course was set. The samples have been gathered for two years; instantaneous samples were drawn from the influent and treated wastewater. Based on daily average values, a general average has obtained. After treatment described above the effluent it's suitable for agriculture reuse; matching characteristics to lay down by the regulations in force parameters.

Keywords
Small wastewater treatment plant, membrane, ozone, water reuse

INTRODUCTION

Environment management is a significant challenge in all countries even if there is a strong legislation to control wastewater and institutional capacity for integrated planning and management. Generally, there are many options for communities in rural area when it comes to appropriate and cost effective technologies for the treatment of wastewater. Also there are many activities that have to d**isposal** wastewater where no public sewer is available and have to treat it on site before discharging it to surface waters or groundwater. Wastewater treatment approaches vary from the conventional centralized systems to the entirely onsite decentralized and trade effluents systems.

These range from simple on-site septic systems for individual homes to highly advanced treatment units for whole communities. While some systems are simply scaled-down versions of large city facilities, they are not always cost-effective solutions and technologies for smaller towns.

Centralized wastewater collection and treatment systems are costly to build and need technical expertise to manage and operate them, especially in areas with low population densities and dispersed households. The decentralized system is not only a long-term solution for small communities but is more reliable and cost effective.

The centralized systems which are usually publicly owned collect and treat large volumes of wastewater for entire large communities, thus making use of large pipes, major excavations and manholes for access (Fisher, 1995; USEPA, 2004). On the other hand, small and decentralized onsite systems treat wastewater of individual homes, buildings and industries (Crites and Tchobanoglous, 1998; Tchobanoglous et al., 2004; USEPA, 2004). The important characteristic that distinguishes this type of wastewater management from larger systems is that there is a much greater potential for collect, treat and reuse/dispose treated wastewater at or closer the generation

point while centralized systems often reuse/dispose far from the generation point.
How can decentralized wastewater treatment protect the environment, public health and water quality? Reducing conventional pollutants, nutrients, and emerging contaminants – decentralized treatment can produce effluent quality that is equal to or higher than other wastewater disposal options. These decentralized systems use the same advanced treatment technologies as discharging systems. Since they use the treatment capacity of the soil, they achieve high quality treatment at a lower cost than other options.
System failure was generally due to poor design, lack of maintenance or inappropriate management.

The aim of this paper was to study a full scale treatment plant for wastewater from train washing system in terms of performance, effluent reuse, treatment efficiencies (BOD, COD, TSS removal), operation and maintenance costs.

MATERIAL AND METHODS

Study area

Present study was conducted at Rome adjacent area to Tuscolana Railways Station - Via Casilina Vecchia in the Italian region Lazio.

Full-scale design, setup and description to

This paper describes the full-scale installation of the WWTP at Trenitalia S.p.A. designed, constructed and installed by GOST Ltd. The WWTP was designed to treat 4 m^3/day of industrial wastewater referred of internal cleaning activities, external washing, emptying waste water of closed-circuit toilets, graffiti removal, etc., of the rolling stock. Rainwater and all the wastewater from the cleaning activities at washing platforms undertake a series of treatments through the treatment plant in order to make the effluent fit the discharge into the ground (Table 4 of the Legislative Decree 152 of 3 April 2006 and subsequent amendments and additions). The treatment processes serial: (1) screening with a screw filter able to keep all the solid materials with size more than 2mm (TSS removal 80-90%), (2) SBR biological treatment plant with 90 m^3 working volume (washing trains wastewater, the first rain water, the second rain water) (removal of 80% TSS and suspended solids, 50% BOD_5), (3) chemical- physical purification (1,5 m^3/h).
However, to guarantee a safe discharge of the treated effluent, tertiary and disinfection treatments are also necessary. In this sense, the system is provided with MBR filtration and ozonisation.

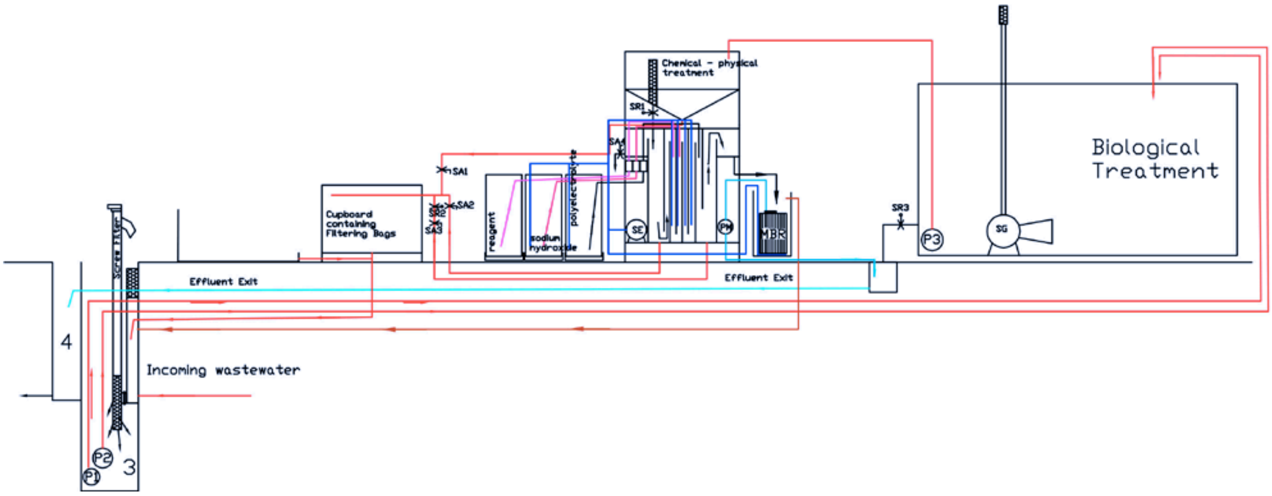


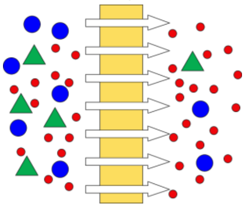
Fig. 2 Flow scheme. P1, P2 - feed pump, P3 - feed pump for chemical-physical plant, PM - MBR extraction pump , SG - jet blower, SE - external blower, SA1 - gate valve for discharge sludge from upper tank, SA2 - gate valve for discharging oil from the separator, SA3 - gate valve for discharge sludge from chemical physical plant, SA4 - oil removal discharge, SR1 - feeding gate valve, SR2 - gate valve sludge discharge, SR3 - gate valve first rain plant, 3 - relaunch/accumulation well, 4 - sewerage output well, MBR – membrane module

Wastewater resulting from the washing process contains significant amounts of suspended solids (TSS), suspended and dissolved organics (COD, BOD_5). Cleaning in place is performed with strong chemicals such as bicomponent detergent that can influence downstream wastewater treatment processes. The COD can vary between 300 and 1200 mg/L, .

Fig.3 wastewater sample

Membrane characteristic

The ability of the membrane depends on the size of pores, types of materials, types of wastewater to be treated, solubility and retention time. Retention is observed due to the concentration change between the retentate (a part of solution that cannot cross over the membrane) and permeate (solution after filtration). Permeability, flux, pressure (TMP) and resistance are the parameters that also need to be considered while conducting MBR process. The flow configuration of membrane processes is orthogonal named dead-end filtrations: the wastewater invests the membrane perpendicularly, the mud (retentate) withheld by the membrane is deposited on the membrane itself acting as a filter layer also determining a reduction in the permeate flux due to the increase of the resistance to filtration. GOST MBR membrane filtration modules consist of bundles of hollow fibres mounted on a strong AISI 304 stainless steel supporting frame and connected by Akulon pipes, very resistant and non-deformable material. The manifolds are interlocking inserted into the frame and are connected to the suction tube with PVC pipes with quick mounting. The support structure of the modules is used to give rigidity to the system. The height of the frame is sufficient to ensure that the fibres remain rather "soft", or better, able to move under air action blown from below the module.



To further reduce any mud, the modules have an integrated air distribution system under the fibres through a blower. The air flowing as bubbles along the fibres generates a higher turbulence system around minimizing the biomass storage on the fibres themselves. Also the system allows a greater degradation of refractory organic compounds. Indeed, the high molecular weight that often characterizes these compounds makes waterproof membrane and therefore significantly increases the contact time in the activated sludge tank, favouring the specific microbial consortia development. The hollow fibres are in PP superficially modified to ensure optimal porosity, able to remove all suspended solids, colloids, bacteria and cysts.

Fig.4. GOST submerged hollow fibre membrane module and bundle (courtesy of GOST MBR solutions).

Table 1. Main features of the membranes:

Fibres material	Polypropylene
Porosity	40 – 50%
Pore size	0,02 -0,2 µm
Outer fibre diameter	0,45 mm
Washing conditions (pH)	7
Washing conditions (temperature)	Tmax = 50 °C
Backwash	SI
Bundle size	Φ 25 x 750 mm
Bundle	1000 fibre
Filtration area of a bundle:	1,00 m²
Filtration surface of a module	126 m²
Working pressure	0,1 – 0,4 bar
Permeate flow average	10 – 15 l/ m² h

The solid-liquid separation occurred in the MBR tank equipped with 1 module submerged hollow fibre membrane with a nominal pore size of 0,02 – 0,002 µm (GOST Ltd.). The total membrane area was 126 m^2. The membrane was operated with an on/off cycle aimed to provide a relaxation time in such way that every 2 min the permeate discharge was stopped for 15 sec for cleaning through backwashing, and the daily operating time of membrane was 21 h. Membrane fouling was reduced by introducing air at the bottom of the membrane module (scouring) as well as by the on-line backwashing with tap water.

Ozone

Ozone is a very powerful oxidant (Redox potential 2,07 V for ozone versus 2,8 V for hydroxyl radical) for water and wastewater treatment, a highly oxidative agent, react directly or via a hydroxyl radical mechanism results into the reduction of organic content with increase of biodegradability of natural organic matter and the efficient inactivation of a wide range of microorganisms (Gottschalk et al., 2000; Takanashi et al., 2002; Xu et al., 2002; Liberti and Notarnicola, 1999). In this sense, ozonation is a recommended technology to be used as an advanced treatment at WWTPs treating various types of food-processing wastewaters as ozone reacts with a wide variety of organic pollutants present in these wastewaters (e.g., phenolic compounds) and it is a clean disinfecting agent leaving no residue after its use. Moreover, Esplugas et al. found ozonation as an economically advantageous technology for the removal of phenol from water by comparison with other classical advanced oxidation methods (O_3/H_2O_2, UV/ H_2O_2, UV/O_3, UV/ H_2O_2/O_3, Fe^{2+}/H_2O_2 and TiO_2 photo catalysis). Consequently, ozonation must be considered as a primary candidate technology for the tertiary treatment of food-processing wastewaters of phenolic nature. Ozonation has also been used to meet discharge requirements for coliform and virus inactivation since the 1970s (Rice et al., 1981). Frequent ozonation for treatment of wastewater and drinking water is due to its ability to oxidize complex organic molecules, phenols, Endocrine Disruptive Chemicals (EDCs) and pharmaceuticals (Zwiener and Frimmel, 2000; Huber et al., 2005; Snyder et al., 2006; Kim and Tanaka, 2010). In combination of microbial disinfection ozonation is an attractive alternative for advanced wastewater treatment (Wert et al., 2007). Recent ozone generation techniques require lower energy consequently; costs are also reduced making the field application of ozonation economically viable (Freire et al., 2001; Jennifer et al., 2010). Accordingly, in this study, the biological degradation and the chemical oxidation by ozone have been studied separately, with an aim of quantifying the COD removal efficiencies. The combined process of ozonation and biological treatment is one of the most promising processes among advanced treatment methods. Ozone gas was produced using an ozone generator previously calibrated. The pure ozone dose was controlled at approximately 20 mgO_3/min for ozonation. The generator produced ozone by the Corona discharge method and was water-cooled. The oxygen was used as a feed gas to this unit and was supplied from the air.

Sample collection

Samples were collected in plastic bottles from the effluent channel and transferred to the laboratory, preserved and stored for further analytical determinations and study. Biological activity such as microbial respiration, chemical activity such as precipitation or pH change, and physical activity such as aeration or high temperature must be kept to a minimum. Methods of preservation include cooling, pH control, and chemical addition. The length of time that a constituent in wastewater will remain stable is related to the character of the component and the preservation method used (APHA, 2005). The influent and effluent samples were collected regularly, one time per month, to investigate the system performance, during its evolution: after installation and start-up and during MBR filtration and ozonisation test. The water quality parameters including BOD_5, COD, E.Coli, TSS, TKN, NH_4^+-N, NO_3^--N, total phosphorus TP, pH values and temperature T°C were determined according to standard methods (APHA, 2005). Influent flow rate and effluent flow rate were monitored continuously by the online real-time systems.

Long-term monitoring. The long-term sampling round was carried out for a period of 4 years (2012 - 2015) to collect data for calculation (detailed is listed in Table 2). The incoming influent and outlet effluent were collected 3 h composite samples with refrigerated samplers both in the context of long-term sampling, to measure COD, Al, Cd, Fe, Ni, Pb, Cu, Zn, TKN, NH_4^+, NO_3^-, NO_2^-, S_T (Total Surfactants). Other registered online data has been the filtration flow rate of MBR membranes.

Analysis

To measure the above parameters were used photochemical commercial test kits (Hach Lange GmbH, Düsseldorf, Germany) LCK type. The pH measurements were done using digital pH meter (Hanna Instruments, Italy). The spectrophotometric analysis was done using XION 500 Dr Lange spectrophotometer (Hach Lange, Italy). Total Nitrogen / Nitrogen ammonia / nitrite / nitrate were measured using the kit Dr Lange LCK238/LCK303/LCK342/LCK339 respectively. Total phosphorus was measured using the kit Dr Lange LCK348. Surfactants Nonionic / Anionic / Cationic were measured using the kit Dr Lange LCK333/LCK 332 / LCK331 respectively.

RESULT AND DISCUSSION

Temperature

Basically, wastewater temperature is a key factor that can affect biological processes for wastewater treatment, especially biological nitrification/denitrification processes. During the present study, influent wastewater temperatures varied from 10.0°C to 27.0°C depending on the season of the year. Refereed of the influent temperature variability the effect on the performance from this study was not clearly observed. The ambient temperature during the winter season reached - 5 °C. The expected results showed matched with the interpretation of (Halling- Sørensen and Jørgensen, 1993) that the attached-growth systems have an advantage in withstanding lower temperatures.

Consequently, the establishment and growth of microorganisms in this system could tolerate the variation of temperature.

COD removal. Results of COD removal efficiency in WWTP during the experiment period in the influent and final effluent during the treatment are presented in Table 1. The COD removal efficiency was 80-90%. It can be seen that the average efficiency of COD removal is approximately 90%.

Table 2. Long term monitoring

Data		pH	COD	Al	Cd	Fe	Ni	Pb	Cu	Zn	NH_3	NO_2	NO_3	St
03.01.2012	Inlet	7,32	385	1,28	0,42	3,0	0,103	0,113	0,379	0,104	12,32	0,037	1,71	7,64
	Exit 1	6,92	98	0,63	0,063	1,343	0,093	0,038	0,171	0,014	6,31	0,63	5,28	4,92
	Exit MBR	7,05	45,2	0,075	0,002	0,211	0,014	0,007	0,024	0,019	1,13	0,025	3,65	0,220
28.04.2012	Inlet	6,1	1218	0,159	0,023	2,43	0,133	0,061	0,172	0,098	38,29	0,217	0,063	5,048
	Exit 1	7,63	121	0,123	0,011	1,069	0,122	0.049	0,098	0,015	21,42	0,813	16,28	2,024
	Exit MBR	6,64	24,3	0,048	0,001	1,04	0,095	0,006	0,046	0,001	16,6	0,451	0,332	0,371
25.07.2012	Inlet	7,31	830	1,02	0,31	0,916	0,323	0,217	0,356	0,263	21,73	0,143	0,114	14,51
	Exit 1	6,02	235	0,036	0,197	0,248	0,149	0,105	0,143	0,097	10,24	0,082	11,51	4,712
	Exit MBR	8,14	55,31	0,001	0,001	0,105	0,083	0,022	0,033	0,028	9,65	0,034	8,78	0,112
14.10.2012	Inlet	6,7	1119	1,19	0,047	1,28	0,275	0,313	0,564	0,114	1,204	0,145	0,367	4,648
	Exit 1	7,36	149	0,72	0,008	0,877	0,218	0,061	0,126	0,032	0,103	0,095	1,36	1,198
	Exit MBR	7,38	67,24	0,098	0,006	0,212	0,152	0,004	0,069	0,014	0,221	0,028	0,843	0,321
03.01.2013	Inlet	7,6	932	0,340	0,099	0,319	0,417	0,146	0,414	0,037	19,2	0,451	0,399	7,58
	Exit 1	6,6	154	0,160	0,0	0,098	0,109	0,073	0,046	0,012	16,6	0,014	1,332	2,29
	Exit MBR	83	88	0,098	0,003	0,051	0,027	0,019	0,012	0,001	4,29	0,011	7,418	0,414
08.04.2013	Inlet	6,7	821	1,511	0,27	8,23	0,932	0,283	0,486	0,488	28,6	0,477	0,091	12,99
	Exit 1	7,23	149	0,231	0,101	2,75	0,278	0,121	0,472	0,377	19,12	0,246	0,089	2,475
	Exit MBR	7,08	68,3	0,016	0,012	0,231	0,018	0,037	0,028	0,112	13,7	0,022	3,03	0,420
14.07.2013	Inlet	8,16	808	1,33	0,014	2,67	0,529	0,401	2,71	0,371	14,73	0,114	0,117	26,56
	Exit 1	5,71	182	0,721	0,009	1,44	0,226	0,311	1,403	0,173	8,28	0,011	1,523	4,907
	Exit MBR	7,28	35,8	0,095	0,001	0,93	0,115	0,093	0,063	0,104	7,19	0,006	4,281	1,761
11.11.2013	Inlet	6,18	322	0,340	0,073	0,195	0,114	0,127	0,388	0,427	18,35	1,532	0.325	11,92
	Exit 1	5,8	19,6	0,160	0,033	0,124	0,035	0,038	0,151	0,152	12,5	0,907	6,67	3,174
	Exit MBR	7,14	21,3	0,028	0,006	0,062	0,024	0,002	0,094	0,048	1,09	0,115	16,8	0,499
06.03.2014	Inlet	8,73	730	0,773	0,029	1,97	0,063	0,215	0,257	0,198	0,274	0,093	0,016	6,27
	Exit 1	6,81	173	0,251	0,007	0,842	0,072	0,104	0,029	0,071	0,115	0,029	0,342	1,141
	Exit MBR	7,53	25,7	0,11	0,002	0,031	0,048	0,042	0,023	0,007	0,021	0,014	0,213	0,367
25.06.2015	Inlet	6,92	321	0,718	0,107	0,788	0,392	0,101	0,370	0,096	0,541	0,063	0,387	3,09
	Exit 1	6,7	115	0,417	0,053	0,336	0,193	0,023	0,316	0,032	0,016	0,025	0,017	1,56
	Exit MBR	7,2	66,5	0,019	0,012	0,172	0,057	0,007	0,034	0,014	0,163	0,112	0,419	0,601
16.10.2015	Inlet	7,03	853	1,29	0,065	3,53	0,238	0,081	0,466	0,261	1,48	0,152	0,171	8,73
	Exit 1	7,11	171	0,015	0,041	1,64	0,113	0,061	0,278	0,224	0,721	0,247	1,08	2,154
	Exit MBR	7,32	14,5	0,003	0,019	0,346	0,008	0,038	0,104	0,216	0,221	0,112	0,186	0,378
03.11.2015	Inlet	6,87	639	1,34	0,081	2,83	0,347	0,087	0,275	0,124	25,53	0,149	0,432	9,73
	Exit 1	7,47	248	0,821	0,075	1,01	0,142	0,024	0,094	O,098	18,39	0,103	1,731	2,66
	Exit MBR	6,34	18,7	0,001	0,038	0,221	0,029	0,007	0,033	0,012	10,45	0,150	8,241	0,296

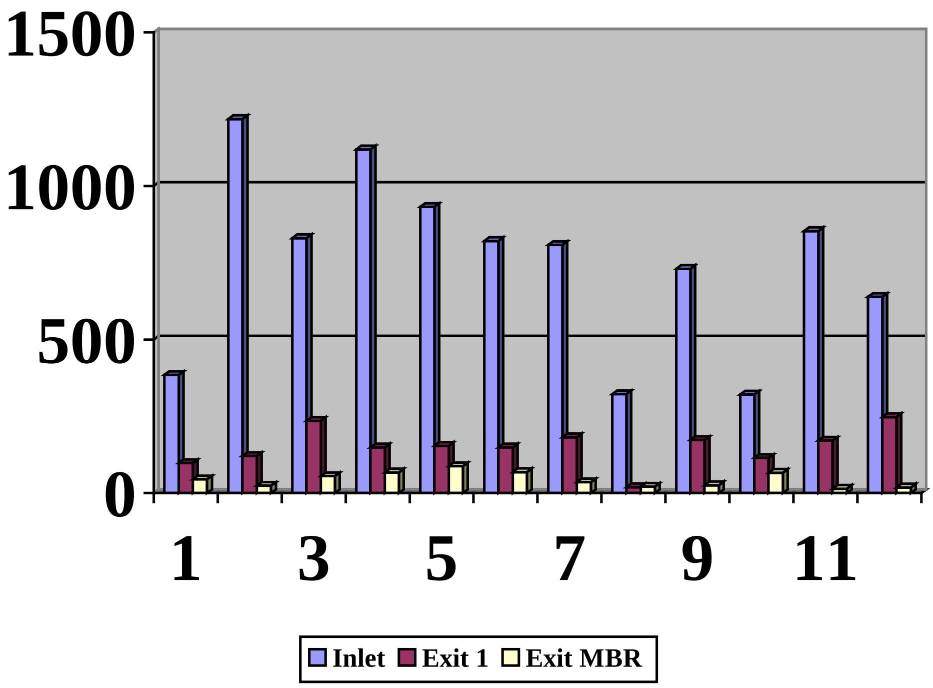


Fig.5 COD Removal

CONCLUSIONS

Providing reliable wastewater treatment – Decentralized wastewater treatment systems can offer as much public health and environmental protection as centralized treatment systems. Like centralized treatment, decentralized treatment systems must be properly designed and constructed and well maintained. More than ever, these systems typically include good monitoring and backup that help prevent adverse discharges. The modern decentralized treatment system is as reliable as other wastewater treatment alternatives, and it is also a cost-effective and sustainable method of treatment for communities

Decentralized wastewater management, if viewed as an alternative to larger, centralized systems, presents perhaps the greatest opportunity for wastewater reclamation and reuse. For example, landscape irrigation of public areas, industrial reuse, or reuse in buildings creates a distributed demand for wastewater. If the production of reclaimed wastewater can be coordinated with the demand, facilities can be constructed close to the site of demand. This arrangement has the potential to achieve large savings in transport of both the untreated and treated wastewater. Furthermore, by treating the wastewater in smaller quantities, the necessary level of treatment can be coordinated with the reuse application. Another opportunity is for the entity reusing the wastewater to invest directly in the construction and operation of the treatment facilities. This type of arrangement is attractive to many industries or users that face difficulty finding a new or secure water source.

The main advantages of WSPs are as follows: produce effluent well-suited to irrigation, have low construction, operation, and maintenance costs, require minimal technical training and skills to operate and maintain low sludge production.

Small and decentralized wastewater treatment systems can protect the environment, public health, and water quality in homes and communities by: providing reliable wastewater treatment, reducing conventional pollutants, nutrients, and emerging contaminants, and mitigating contamination and health risks associated with wastewater

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