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CSO treatment technologies – a comprehensive design and resource manual

By:

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CSO treatment technologies – a comprehensive design and resource manual

G. Zukovs, G. and J. Marsalek

ABSTRACT

A newly produced manual focuses on managing combined sewer overflows (CSOs) in the context of Canadian conditions and environmental regulations. Review of approaches used in Canada and elsewhere indicated a growing interest in CSO management options involving CSO treatment and, consequently, the manual focused on an overview of treatment technologies. Towards this end, the following processes have been reviewed: screening, degritting, retention treatment basins (RTBs), chemically enhanced high rate sedimentation, Continuous Deflective Separation® (CDS), hydrodynamic (vortex) separation, dissolved air flotation, Fuzzy Filters®, chlorination/dechlorination, and UV Irradiation. Even though the conventional systems (retention treatment basins) still dominate the current Canadian practice, favourable results of the ongoing tests of new technologies (chemically enhanced high rate sedimentation, refined vortex separation, continuous deflective separation®, dissolved air flotation, and Fuzzy Filters®) may change this situation dramatically in next 5 years.

NWRI RESEARCH SUMMARY

Plain language title

Manual for treatment of combined sewer overflows (CSOs)

What is the problem and what do scientists already know about it?

Combined sewer overflows impair water quality and beneficial uses of receiving waters, and need to be addressed in water pollution control planning. In recent years, municipal wastewater authorities were exploring new and innovative technologies specifically designed for CSO treatment. However, in many cases, the basic information needed by municipal decision makers to evaluate, select and design CSO treatment technologies has been difficult to assemble. To remedy this situation, a new CSO treatment manual has been developed.

Why did NWRI do this study?

CSO are recognized as major contributors to the water pollution encountered in the Great Lakes Areas of Concern. The delisting of such areas requires the abatement of CSO pollution using various measures, including CSO treatment.

What were the results?

The CSO treatment manual has been produced and serves two purposes: (a) To provide information about physical and physical/chemical CSO treatment technologies, and (b) to assist users in the selection, design, and application of CSO treatment technologies.

How will these results be used?

The results will be used by municipalities for planning and implementing CSO treatment.

Who were our main partners in the study?

The main partners were XCG Consultants Ltd. (the project contractor), The City of Welland and the Great Lakes Sustainability Fund (Burlington, Ontario).

Méthodes de traitement des trop-pleins d'égout unitaire – Guide de conception et des ressources

G. Zukovs, G. et J. Marsalek

RÉSUMÉ

Un guide sur la gestion des trop-pleins d'égout unitaire (TPEU) au Canada, qui tient compte de la réglementation environnementale, a récemment été publié. Un examen des méthodes utilisées au Canada et dans d'autres pays a révélé un intérêt grandissant pour la gestion des TPEU, notamment pour leur traitement. Par conséquent, le guide passe en revue les différentes méthodes de traitement. Les procédés suivants ont été étudiés à cette fin : dégrillage, dessablage, rétention en bassin, décantation rapide avec ajout de produits chimiques, séparation continue (Continuous Deflective Separation[MD]), séparation hydrodynamique (hydrocyclonage), flottation à air dissous, filtration (Fuzzy Filters[MD]), chloration/déchloration, rayonnement ultraviolet. Même si les systèmes classiques (bassins de rétention) sont les plus utilisés actuellement au Canada, les résultats concluants obtenus lors d'essais de nouvelles technologies (décantation rapide avec ajout de produits chimiques, hydrocyclonage, séparation continue par déflexion[MD], flottation à air dissous et filtration Fuzzy Filters[MD]) pourraient modifier cette situation de façon radicale au cours des cinq prochaines années.

Sommaire des recherches de l'INRE

Titre en langage clair

Guide sur le traitement des trop-pleins d'égout unitaire

Quel est le problème et que savent les chercheurs à ce sujet?

Les trop-pleins d'égout unitaire (TPSU) nuisent à la qualité de l'eau et aux utilisations bénéfiques des eaux réceptrices et doivent être examinés lors de la planification des mesures de lutte contre la pollution de l'eau. Au cours des dernières années, les organismes municipaux responsables des eaux usées ont examiné des technologies nouvelles et innovatrices conçues spécialement pour le traitement des TPEU. Cependant, dans de nombreux cas, il nous a été difficile de regrouper l'information de base dont les décideurs municipaux ont besoin pour évaluer, sélectionner et concevoir des méthodes de traitement des TPEU. Afin de remédier à cette situation, un nouveau guide sur le traitement des TPEU a été préparé.

Pourquoi l'INRE a-t-il effectué cette étude?

Les TPEU sont une source majeure de pollution de l'eau dans les secteurs préoccupants des Grands Lacs. Pour que ces secteurs ne soient plus considérés comme tels, il faut réduire la pollution engendrée par les TPEU par divers moyens, notamment par le traitement des TPEU.

Quels sont les résultats?

Le guide a deux objectifs : a) fournir de l'information sur les procédés de traitement physiques et physico-chimiques des TPEU, et (b) aider les utilisateurs à sélectionner, concevoir et appliquer des méthodes de traitement des TPEU.

Comment ces résultats seront-ils utilisés?

Les municipalités utiliseront les résultats pour planifier le traitement des TPEU et y procéder.

Quels étaient nos principaux partenaires dans cette étude?

Les principaux partenaires sont XCG Consultants Ltd. (l'entrepreneur), la Ville de Welland et le Fonds de durabilité des Grands Lacs (Burlington, Ontario).

CSO TREATMENT TECHNOLOGIES – A COMPREHENSIVE DESIGN AND RESOURCE MANUAL

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ABSTRACT

A newly produced manual focuses on managing combined sewer overflows (CSOs) in the context of Canadian conditions and environmental regulations. Review of approaches used in Canada and elsewhere indicated a growing interest in CSO management options involving CSO treatment and, consequently, the manual focused on an overview of treatment technologies. Towards this end, the following processes have been reviewed: screening, degritting, retention treatment basins (RTBs), chemically enhanced high rate sedimentation, Continuous Deflective Separation® (CDS), hydrodynamic (vortex) separation, dissolved air flotation, Fuzzy Filters®, chlorination/dechlorination, and UV Irradiation. Even though the conventional systems (retention treatment basins) still dominate the current Canadian practice, favourable results of the ongoing tests of new technologies (chemically enhanced high rate sedimentation, refined vortex separation, continuous deflective separation®, dissolved air flotation, and Fuzzy Filters®) may change this situation dramatically in next 5 years.

KEYWORDS

Combined sewer overflows (CSO); CSO management; CSO manual; CSO abatement; treatment technologies

INTRODUCTION

Combined sewer overflows (CSOs) are recognised as significant causes of the impairment of water quality and beneficial uses of receiving waters. CSO impacts are rather varied and can be considered under three major categories of concern, water quality changes, public health risks, and aesthetic deterioration (House *et al.*, 1993). The impacted water uses generally include water based recreation, fishing, water supply and receiving waters ecosystem functions (Lijklema *et al.*, 1993). It is of interest to note that different categories of impacts receive different priority ranking in various jurisdictions and this has direct bearing on remediation measures applied. For example, in Canada and USA, there is a great emphasis on "fishable and swimmable" waters, with concomitant needs to deal with faecal pollution of CSOs. On the other hand, recent literature from UK indicates a great deal of attention being paid to dealing with "aesthetic pollutants", which would emphasize the use of screening technology (Saul, 2003). Thus, the methods and approaches to managing CSO pollution need to reflect national regulations and local priorities. In general, CSO management includes a number of principal methods, including control of stormwater input into combined sewers (including sewer separation), CSO storage (and treatment) with return of stored wastewater to the central treatment plant when capacity permits, CSO treatment in special facilities located either at the central WTP or at overflow points, and improved system operation by real time control. Increasingly, municipal wastewater authorities are exploring new and innovative treatment technologies specifically designed for CSOs (Cronqvist *et al.*, 2004). These technologies, when applied as part of an overall wastewater management strategy, can produce efficient and cost-effective solutions for CSOs. However, like all technologies they require systematic design and proper operation. In many cases the basic information

needed by municipal decision makers and their engineers to evaluate, select and design CSO treatment technologies has been difficult to assemble. Recognising this need, the Government of Canada through the Great Lakes Sustainability Fund has recently developed a CSO Treatment Technologies Manual (XCG, 2004). The objectives of the manual are twofold: (a) to provide information about physical and physical-chemical CSO treatment technologies; and, (b) to assist users in the selection, design, and application of CSO treatment technologies. The paper that follows provides an overview of the manual.

CSO ABATEMENT PROGRAM PLANNING

CSO abatement program development is a systematic process building on an understanding of the collection/treatment system, evaluation and selection of a preferred set of operational and structural measures meeting the program objectives, and the preparation of an implementation plan for specific facilities and non-structural program elements. The first critical question is that of the program scope – is it designed just to abate CSOs, or is it intended to meet water quality goals by addressing other pollution sources as well? Program goals are multi-dimensional and address environmental concerns, public health issues, collection/treatment system impacts (e.g., basement flooding, STP impacts), regulatory requirements, and community concerns (odours, aesthetics, the siting of facilities, etc.). A three phase planning approach is recommended as shown in Fig. 1.

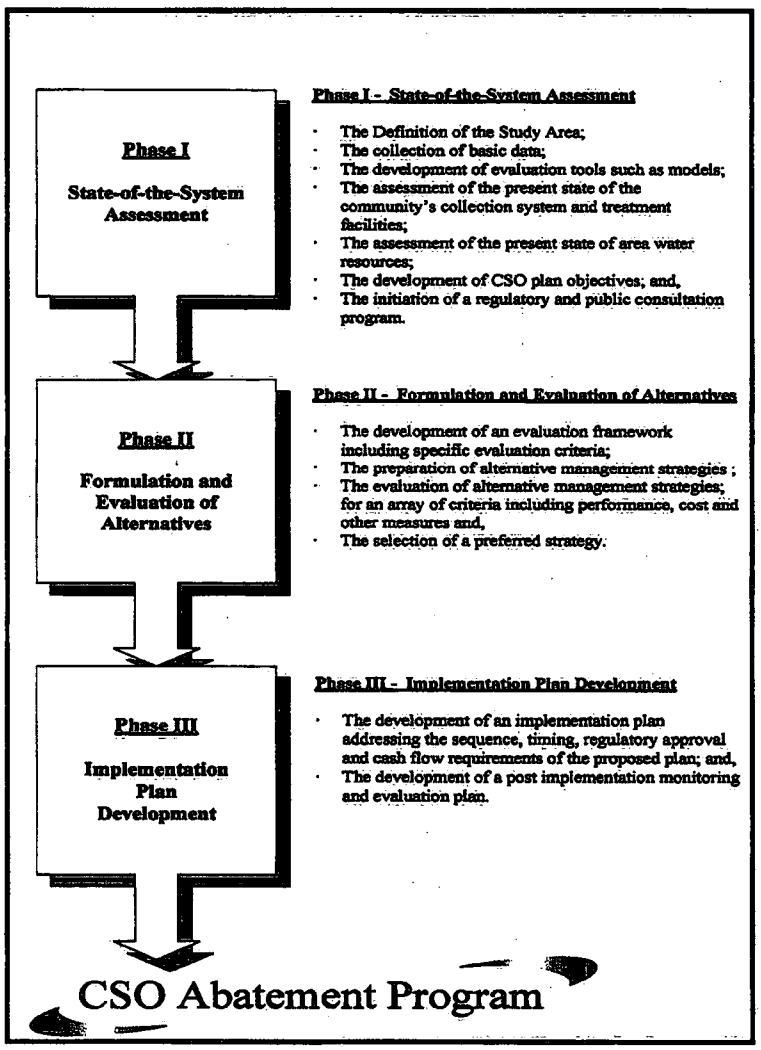

Fig. 1. CSO Program Planning

Canadian regulatory requirements

Regulatory requirements are developed at various levels, ranging from national, to territorial (provincial) and local requirements. In Canada, the management of CSOs is a multi-jurisdictional responsibility, with federal government enforcing broad environmental acts dealing with protection of fisheries (Canada Fisheries Act) and prohibition of release of toxicants (Canadian Environmental Protection Act, CEPA). Regulations addressing specifically CSOs are issued at the provincial level and may be supplemented by municipal policies and bylaws. There are two provincial policies in existence, in the provinces of British Columbia and Ontario (XCG, 2004). The Ontario CSO policy, known as Procedure F-5-5, Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems, is particularly focused on CSO treatment and can be summarized as follows (MOE, undated): (a) Volumetric control – 90% of wet weather flows; (b) Carbonaceous biochemical oxygen demand ($cBOD_5$) – 30% removal; (c) Total suspended solids (TSS) – 50% removal and not to exceed 90 mg/L for more than 50% of the time; (d) Disinfection – monthly geometric mean not exceeding 1,000 E. coli per 100 mL during wet weather. All these regulations apply to a seven-month period commencing within 15 days of April 1 of an average year.

CSO TREATMENT TECHNOLOGIES

An extensive literature survey identified many CSO treatment technologies currently applied, often arranged in series in a treatment train, in various countries (XCG, 2004). For the purpose of further discussion, they are divided into the following ten sections: Screening, Degritting, Retention treatment basins (RTBs), Chemically enhanced high rate sedimentation, Continuous deflective separation (CDS), Hydrodynamic (vortex) separation, dissolved air flotation, Fuzzy filtration, Chlorination/dechlorination, and UV Irradiation. Besides treatment objectives, all these processes can meet additional CSO control objectives, including 90% volumetric control.

Screening technologies

Screening technologies are applied either as a part of an overall CSO treatment process train, usually for pre-treatment or effluent polishing in association with CSO treatment facilities providing primary equivalent treatment, or as stand alone devices providing lower than primary- equivalent treatment. The latter application serves to control gross solids including floatable materials (aesthetic pollutants) in overflows. Generally, removal efficiencies or effluent requirements for particulate solids or other parameters are not specified for screening devices. Screens remove solids and floatables by direct straining of particles larger than the screen openings and filtering of smaller particles by straining flow through layer of solids already deposited on the screen. Two types of screens are recognised, coarse bar screens with bar spacing greater than 25 mm and fine screens with rounded or slotted openings of 4 to 25 mm of clear space. Vertical coarse and fine screens require considerable head room and footprint, weir mounted screens are lower in profile and applicable to satellite locations at overflows. No pre-treatment is required for screens. The performance requirements for screens follow from the overall treatment train requirements, or those specified as minimum controls. In applications, the screen performance is neither specified nor measured. In research studies, screen pollutant removal efficiencies, R, are calculated as $R\ [\%] = 100^* (M_i - M_e)/M_i$, where M_i is the influent mass, M_e is the effluent mass. Reported Rs were as high as 80-99% for floatables and 18-86% for TSS, depending on the screen design. Recognising that screens may improve solids retention efficiency of other devices (e.g., RTBs), another performance parameter is defined as the screening retention value (SRV). In controlled testing, SRVs of various screens ranged from 28 to 63% (UKWIR, 2001). Good representative data on screen capital costs are available, averaging about \$1.3 million USD/m^3/s, and annual O&M costs of \$45 USD/m^3 of flow (Field 2002). Numerous examples of screen installations in UK and USA were reported (XCG, 2004).

Degritting

Degritting removes high density, inorganic solids such as sand, gravel and cinders from CSOs in order to reduce the risk of deposition in downstream pipes and minimise equipment abrasion. In CSO treatment, degritting is used as a required or optional pre-treatment in advance, or as a part, of other unit processes. Removal efficiencies or effluent requirements for particulate solids or other parameters are not specified for degritting devices. Degritting is accomplished in grit chambers designed to remove solids having specific gravities of 2.65 or greater, a standard used to separate inorganic solids from putrescible organics. Three types of degritting chambers are commonly used in general wastewater applications: horizontal flow grit chambers, aerated grit chambers, and vortex-type grit chambers. Horizontal flow chambers have a long history and are similar to settling basins. Aerated chambers are designed to diffuse compressed air through the tank in order to maintain organic particles in suspension while allowing heavier grit to settle. Vortex-type degritters have gained popularity because of compact size, portability, and the ease of separating fine grit from the flow by vortex action. A number of vortex degritter designs are commercially available. The degritter can be used as a preliminary process near the headworks of the treatment facility to protect the downstream equipment. Floatables control, such as coarse screening, should be used prior to degritting. With respect to performance, degritters can generally remove grit sizes > 0.3 mm in diameter and improved designs can remove grit as small as 0.05 mm. Typical systems target 95% removal of 0.1- 0.2 mm materials. The number of reported CSO degritter installations is relatively low and, consequently, the available cost information is highly uncertain, and depends on the type, design and capacity (XCG, 2004).

Retention treatment basins (RTBs)

Retention treatment basins are designed to remove settleable solids and floatables, but provisions can be made to add additional treatment capabilities, such as coagulant addition for soluble or colloidal contaminant removal, screens for floatables control, or disinfection. RTBs can provide primary equivalent treatment with respect to removals of solids (TSS) and BOD. RTBs are applied at satellite locations or as integrated or stand alone facilities at wastewater treatment plants (WWTPs). TSS and $cBOD_5$ performance objectives can be specified as percentage removal requirements and as effluent concentration limits. Additional criteria may be specified for bacteria counts in the effluent (where disinfection is added) and removal of gross solids and floatables. Floatables are usually removed by baffle or skimmer arrangements or by installation of screens. An automated cleaning system is usually a part of the RTB facility. RTBs generally consist of several compartments to allow smaller overflow events to be captured and/or treated without the utilisation of the entire facility. The division of the storage volume of the RTB into separate compartments also allows using different compartments for other operations such as disinfection. RTB can be used as a stand-alone technology in CSO applications or as a part of a treatment train for solids removal and disinfection. Coarse pre-screening is recommended for better performance. RTBs may remove more than 90% of floatables and a high percentage of settleable solids (SS). Average removals of TSS and BOD in the Rouge River demonstration project were 66%, for both constituents (XCG, 2004). Reported RTB costs vary, depending on whether land costs are included, in the range from $500 to $2,000 USD per m^3 of storage (XCG, 2004). The lower costs correspond to large basins, the higher to small basins. There are numerous RTB applications in Canada, Europe (particularly in Germany) and USA.

Chemically enhanced high-rate sedimentation (CEHRS)

CEHRS is a term describing two commercial technologies that employ ballasted coagulation assisted settling: Actiflo® and DensaDeg®. The CEHRS technologies are applied to remove gross solids (through screening), particulate solids and associated contaminants (e.g. $cBOD_5$), as well as colloidal solids through coagulation and sedimentation. Soluble contaminants such as phosphorus and selected heavy metals are also removed, and possibly even oil and grease. Thus, CEHRS facilities can be implemented as primary-equivalent treatment removing TSS, BOD, grit, floatables and possibly bacteria, where disinfection is added. CEHRS facilities are applied as satellite facilities, or stand-alone or integrated units at WWTPs. With respect to technology, CEHRS, also known as ballasted flocculation, is a process that introduces coagulation and flocculation agents during high speed mixing to promote the settling of solids. CEHRS tanks consist of

compartmentalised units in which coagulation/flocculation and sedimentation occur. Wastewater enters the first chamber where suspended and colloidal particles are destabilised. The second chamber is a flocculation centre where polymers and ballast (i.e., microsand) are added and gently mixed. The third chamber is a clarifier where solid/liquid separation occurs with the aid of a high rate settler. The CEHRS system requires upstream preliminary screening and either external or integral degritting before the flow can be treated. The reported CEHRS performance indicates TSS, TP and heavy metal removals of 80-95%, BOD removals of 50-80%, and soluble BOD and TKN removals of 10-20%, at high surface overflow rates (SOR) (> 100 m/h). CEHRS is still a relatively new technology for CSO applications, with relatively few operational plants, but a fair number of pilot trials (XCG, 2004). Thus, cost estimation is difficult at this time.

Hydrodynamic (vortex) separation

Vortex separators are versatile devices which can be employed with in-vessel coagulant addition and/or chemical disinfection, integral fine screens, and, add-on disinfection. Separators do not necessarily require pre-treatment, but most are preceded by coarse screens. Separators produce significant quantities of underflow, which need to be transported to and treated at a WWTP. Vortex separators can be applied in satellite facilities or as a part of an integrated or stand alone facility at a WWTP. The vortex units operate in a SOR range from 3 to 150 m/h. Vortex separators intended for use as primary-equivalent treatment must address TSS and BOD within their treatment objectives, and can be extended to remove other particulate associated pollutants with enhanced separator treatment using in-vessel coagulant addition. Parameters such as buoyant or neutral density floatable materials may be added to treatment objectives but usually as non-numeric criteria. With respect to the process technology, the vortex separator is a static device designed to remove floatables and settleable solids by a swirling motion produced in the cylindrical chamber, with retention of floatables by a scum plate. The leading vortex designs are the Fluidsep® vortex separator, the Storm King® hydrodynamic separator, and the US EPA Swirl Concentrator. There are hundreds of vortex installations in Europe, North America and Japan (Field and O'Connor, 1996; WEF, 1999). The reported performance of vortex separators widely varies, with TSS removals ranging from 0 to 75% (XCG, 2004). The capital costs of separators also broadly vary, ranging from $80,000 to $600,000 per m^3/s.

Continuous deflective separation® (CDS)

Continuous Deflective Separation (CDS®) units are designed to remove gross debris, particulate solids and associated pollutants by an indirect non-mechanical screening mechanism, operating as satellite or central facilities at the WWTP. The CDS® unit does not require pre-treatment (though coarse screens improve operation) and can be designed with an underflow or be fitted with a sump collecting debris. Where intended to provide primary-equivalent treatment, the treatment objectives must address TSS and BOD, and possibly floatables. With respect to treatment technology, CDS® units are designed to induce a continual flow of liquid passing over the face of a special cylindrical separation screen, where the inflow and associated pollutants are deflected away from the main flow stream and are captured in the central chamber, while the rest of the flow passes through the screen and exits via the outlet pipe. The solids contained within the separation chamber are kept in a continuous circular motion generated by the incoming flow, which keeps solids in the chamber from blocking the perforated screen. Ultimately, the heavier solids settle into the containment sump, while floatables stay in the central chamber. Depending on the nature of the applications, the solids in the sump are removed by various means. In applications where the unit is placed underground, the collected solids can be returned to the sewer by gravity or using an underflow pump. Typically, a screen aperture of 4.7 mm is used for CSO applications or for runoff with large amount of gross solids and debris. Because of limited CSO installations, only limited performance information is available. The available cost information is also limited. Several CDS® units are currently being evaluated for CSO applications at various locations in the USA (XCG, 2004).

Dissolved air flotation (DAF)

Dissolved Air Flotation (DAF) technologies are designed to remove suspended solids, oils and dissolved contaminants from pre-treated CSOs, at satellite or centrally located facilities. DAF units intended to

provide primary-equivalent treatment must address TSS and BOD in treatment objectives. DAF technologies remove suspended solids, oils, and other dissolved pollutants from CSOs via the attachment of fine air bubbles to CSO particulate matter as they are carried through the DAF chamber to the water surface for removal. These bubbles, generally less than 100 microns in diameter, are created by high-pressure water saturated with dissolved air fed into the front of the flotation space in a DAF tank. The dispersion water is normally 5 to 15% of the amount of the treated water. The thickness of the bubble bed is about 80 to 120 cm, with an upward flow up to 10 to 15 m/h. The DAF units require pre-treatment by screening and degritting. In terms of performance, in addition to removing suspended solids and floatables such as oil and grease, DAF systems were found capable of removing BOD, COD, phosphorus and nitrogen from CSOs. Results from the full scale demonstration facility at Racine, Wisconsin indicate TP, COD, BOD and SS removals in the range from 53 to 70%. Even though the DAF technology is widely used in wastewater treatment, the number of applications to CSO treatment is limited. The design of DAF systems includes bench-scale tests and pilot-scale demonstration. Actual costs vary widely due to site-specific conditions and little data is available (XCG, 2004).

Fuzzy Filters®

A Fuzzy Filter® is a compressible media filter system providing high solids removals through the use of synthetic fibre spheres. Fuzzy Filters® are typically used as a 'polishing' step in a more complex CSO treatment train, which may include other physical separation technologies upstream (removal of grit and coarse floatables) and UV disinfection downstream of the unit. In CSO applications, Fuzzy Filters® were used to treat effluents from vortex separators and a continuous deflective separator, followed by UV treatment (XCG, 2004). Fuzzy Filters® could be employed at satellite locations, but until more experience is gained with automated operation, their applications at WWTP locations are preferred. With respect to treatment technology, the Fuzzy Filter® is a proprietary compressible media filter system that provides a high rate of solids removal through the use of synthetic fibre spheres. The media bed between two horizontal plates is composed of fibrous balls that are compressed to achieve variable particle removal down to 4 microns. The lower plate is fixed in position, while the top plate is movable to allow its porosity (void) ratio to be modified. The porosity of the uncompressed, quasi-spherical filter media (approximately 3.2 cm in diameter) is about 85%. The media is renewed by air sparging that fluidizes and expands the bed to mechanically release captured solids; no clean water is used. The recommended SOR is 73 m/h (Caliskaner *et al.*, 1999). The system is fully automated and requires very small footprint. Fuzzy Filter® is still a relatively new technology for CSO applications. There are currently no permanent CSO installations, but three full-scale demonstration facilities are being tested in the U.S. The performance of Fuzzy Filter® generally decreases with increasing loading rates and removal efficiencies are negatively affected by an increase in influent pollutant concentrations. TSS removals from 35 to 70%, metal removals 50-70%, and BOD removals of 17% were reported in the literature (XCG, 2004). The cost information on Fuzzy Filter® applications to CSOs is sparse.

Chlorination/dechlorination

Chlorination reduces the densities of bacteria, viruses and other microorganisms in CSOs. Chlorination must be used in conjunction with other unit processes capable of meeting primary equivalent treatment requirements. It is often employed in a separate contactor following pre-treatment and solids separation processes, though it may be also be incorporated directly in a RTB. Chlorination can be applied in satellite or WWTP integrated or stand-alone facilities. Due to the toxicity of residual chlorine to aquatic life, chlorination is followed by dechlorination, which removes residual chlorine by chemical additions. The related CSO treatment objectives refer to a target density of bacteria, e.g., 1,000 *E. coli* org./100 mL. For dechlorination, the treatment objective is zero residual chlorine in the effluent. Typical contact times for CSO facilities range from 1 to 10 minutes with chlorine dosages ranging from 2.6 to 25 mg/L. Disinfection of CSO is typically performed at the later stages of the treatment train. Although, technically speaking, pre-treatment is not required, it is highly recommended because suspended and colloidal solids removal helps reduce the chlorine demand of the wastewater as well as improve overall performance. The most commonly used chemicals for dechlorination are sulphur dioxide and sodium bisulphite. The performance of

chlorination very much depends on the characteristics of the influent wastewater; US experience indicates faecal coliform reductions from 3-4 log to 6 log. Both capital and O&M costs are highly variable and difficult to estimate. Numerous examples of CSO C/D applications include the Rouge River Demonstration Project (Michigan) with nine CSO facilities. For the Rouge River facilities chlorine is dosed at 10-11.6 mg/L for flow rates of 5.4-30.2 m^3/s, and contact times between 20 to 30 minutes (XCG, 2004).

Ultraviolet irradiation

Ultraviolet (UV) irradiation is used to reduce the densities of bacteria, viruses and other microorganisms, including parasites, in CSOs. UV irradiation must be used in conjunction with other unit processes capable of meeting primary-equivalent treatment requirements. UV irradiation employs a separate contactor following pre-treatment and solids separation processes and is applied either at satellite or WWTP facilities. The treatment objectives for UV irradiation are removals of bacteria and other organisms, with a target density, e.g., 1,000 *E. coli*/100 mL. The effectiveness of UV disinfection depends on factors such as the concentration of TSS, size of particles present in the wastewater, the concentration of UV absorbing components and the concentration of the target microorganisms. Disinfection of CSO is typically performed at the later stages of the treatment train. UV disinfection requires preliminary treatment such that solids that interfere with UV radiation via absorbance or scattering can be eliminated as much as possible. This may involve screening, chemically assisted primary settling, or primary settling alone to reduce suspended solids concentration and increase transmissivity. In addition, consideration must also be given to pre-treatment processes that may generate compounds which can lower the effectiveness of UV disinfection (e.g., iron salts used in chemical treatment may absorb UV during disinfection). The existing CSO applications of UV disinfection are limited. Depending on the treated CSO media quality, reductions of 2 to 5 log were reported (XCG, 2004).

CONCLUSIONS

The interest in CSO treatment technologies has increased worldwide and this is reflected in large progress in this field during the last 10 years or so. New technologies have been developed or refined for CSO applications and the existing ones in the wastewater treatment field have been adapted to CSO treatment. Thus, CSO managers have now a range of technical alternatives to choose from when dealing with CSO treatment. In terms of the existing (i.e., in 2004) applications, the conventional systems (retention treatment basins) extended for new processes in pre- and post-treatment are still preferred, but attention is paid to the ongoing field tests of new technologies. Depending on testing results, large changes with respect to preferred CSO treatment technologies can be expected within next 5 years.

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