ORAL & IMPLANTOLOGY

review

DENTAL UNIT WASTEWATER, A CURRENT ENVIRONMENTAL PROBLEM: A SISTEMATIC REVIEW

M.E. CATALDI[1], S. AL RAKAYAN[1], C. ARCURI[2], R. CONDÒ[2]

[1]*PhD in Materials for Health, Environment and Energy, Department of Clinical Sciences and Translational Medicine, University of Rome "Tor Vergata", Rome, Italy*

[2] *Department of Clinical Sciences and Translational Medicine, University of Rome "Tor Vergata", Rome, Italy*

SUMMARY

The dental unit waters are divided in two different groups, because of their chemical and microbial composition proprieties: in the first there is the "incoming dental unit water", drinking water that arrived directly in the dental chair unit through the municipal water system; in the second there is the "waste water", that represents the whole dental unit waste water. Regarding the lack of a complete systematic review on the quality of dental unit wastewater, the aim of the current research was to systematically study the incoming dental unit water and the waste one, focusing the attention on the problem of the wastewater contamination and its regulations.

Materials and methods. A systematic literature review of the last 17 years was conducted on the topic of dental unit wastewater. Italian and English were the languages chosen for the papers research.

Studies were searched in PubMed, Medline and Cochrane, with regard to inclusion criteria.

Results. The investigation and analysis of the two papers group revealed the presence of many information and scientific studies on the incoming dental unit water contamination, in contrast not much in literature about dental unit wastewater.

Conclusions. The results revealed that dental unit wastewater is a problem underestimated by the scientific community, with the exception of dental amalgam wastes.

In Italy there is a sentence of "Corte di Cassazione Penale, sez III, sentenza 17 gennaio 2013, n 2340" that regularized dental wastewaters as industrial ones, so they are inadequate to be disposed as domestic waters; but, at the same time, there isn't a specific law that regulates this king of waste.

Key words: dental unit wastewaters, dental unit incoming water, systematic review.

Introduction

The issue of microbial water contamination in dental unit waterlines was reported for the first time in 1963 by Blake's researches (1); this was followed by numerous studies describing how dental unit waterlines were contaminated during dental practices (2-4) and how to eliminate biofilm and microorganisms in mechanical (filtration) and chemical (hydrogen peroxide, chlorexidine gluconate, sodium hypochlorite) ways (5).

The dental unit waters are divided in two different groups, because of their chemical and microbial composition proprieties: in the first there is the "incoming dental unit water", drinking water that arrived directly in the dental chair unit through the municipal water system; in the second there is the "waste water", that represents the whole dental unit waste water (6).

The guidelines of the Centers for Disease Control (CDC) for dental healthcare setting recommend the use of drinking water observing regulatory standards (≤ 500 CFU/ml of heterotrophic water bacteria) established by Environmental

Protection Agency (EPA) (7).
This directive is important to prevent the microbial incoming water contamination problem but don't guaranteed the sterility of the waste water, that's the main topic of this study.

Incoming dental unit water

Dental chair units use water to cool and irrigate its supplied instruments, tooth surfaces and provide rinse water during dental treatment; in addition it's also supplied to the dental units cup filler outlet that is used by patients for oral rinsing and to the bowl-rinse outlet that rinses the dental units spittoon (6).
The dental unit is equipped with an elaborate loom of interconnected narrow-bore (2-3 mm internal diameter) flexible plastic tubing called dental unit waterlines that supply water to all of the dental unit instruments, cup-filler and bowl-rinse water outles (8, 9).

The kind of water used in the dental unit is the drinking water, a water with properties suitable for human consumption according to the parameters established by the European Directive 98/83/EC (Table 1) and Legislative Decree 31/2001. Drinking water should have an extremely low bacterial content, with total absence of pathogenic bacteria, such as Pseudomonas and Legionella; but doesn't mean that drinking water is sterile, rather it contains a microbial flora which is generally harmless to humans (10).
The inner surfaces of dental unit waterlines tubing, due to the texture and plastic composition, are particularly susceptible to biofilm formation (11). Biofilms are populations of microorganisms growing on a surface and enclosed in an exopolysaccharide matrix; it forms when bacteria adhere to surfaces in some form of watery environment and begin to excrete a slimy, gluelike substance that can stick to all kinds of materials. Biofilms can be formed by a single bacterial species, but more often consist of many species of bacteria, as well as fungi, algae, protozoa, debris, and corrosion prod-

Table 1 - Limits set by current European legislation (98/83/CE) about values of water for human consumption.

Parameter	**Directive CEE/CEEA/CE n°83 of 03/11/1998 (Parameter value)**
Escherichia Coli	0
Enterococchi	0
Clostridium Perfringens	0
Coliform bacteria	0
Antimony	5 µg/l
Arsenic	10 µg/l
Benzene	1 µg/l
Borio	1 µg/l
Cadmium	5 µg/l
Chrome	50 µg/l
Copper	1 µg/l
Cyanide	50 µg/l
Lead	10 µg/l
Mercury	1 µg/l
Nichel	20 µg/l

ucts. Essentially, a biofilm may form on any surface exposed to bacteria and some amount of water, like in the dental unit (8).
Once formed, biofilm is very difficult to destroy. Protected by the polysaccharides, microbes living in a biofilm are up to 1000 times more resistant to disinfection, causing serious problems including medical/dental device-related and healthcare-associated infections (11).
The quality of incoming water is considerable important because both patients and dental team are regularly exposed to water and aerosols generated by dental instruments; so the presence of high levels of microbial contamination could be a health problem for dentists and patients (12).
Today has been suggested an integrate approach in order to reduce this problems, which includes waterline flushing, independent water reservoir systems, distilled or sterilized water, inline micro pore filtration, periodic or continuous chemical disinfection (hydrogen peroxide, sodium hypochlorite, chlorine dioxide) and anti-retraction valves (7, 13).
Among this instruments, the "waterlines filters" are the most widespread; specifically designed for use with dental units include micropore inline filters that must be placed on each water delivery line.
Usually positioned on each water-bearing line, near the handpiece or air-water syringe, microfilters typically use a 0,2 micron membrane to trap free-floating microorganisms before they can be released in the effluent (14).

Dental unit wastewater

Dental unit wastewater represents the whole liquid wastes of dental unit; waters coming from the aspiration system and the bowl-rinse water outlet (6). In Italy, as the incoming dental unit water, also the dental unit drainpipes are directly connected to the urban sewer system, thanks to specific municipal permissions (15).
In this way the dental unit wastewater are legally considered as domestic wastewater, that is wastewater coming from human metabolism and domestic activities, and so suitable to be introduced in the urban sewer system.
Recently, in 2013, the Italian "Corte di Cassazione Penale, sez III, sentenza 17 gennaio 2013, n°2340" judged dental unit wastewater as industrial wastewater, that is wastewater of industrial or commercial buildings, so unsuitable for the urban sewer system (16).
At the present time, there are not much scientific paper analysing the dental wastewater composition (17-21) and the whole papers deal the dental amalgam pollution problem.
The release of amalgam particles into the dental office wastewater is a matter of particular concern as amalgam particles could then be discharged into environment, in fact was estimated that dental offices could contribute from 8 to 14% of the total mercury load to wastewater treatment plants (22).
The particle sized of amalgam in wastewater range from large visible particles (over 3 mm) to a sub-micron colloidal suspension (less than 0,01 mm); in an attempt to reduce the amount of amalgam in dental office wastewater reaching the treatment plants, amalgam separators are gradually being installed in dental offices worldwide. This separators use one or multiple technologies to remove amalgam from dental office wastewater, such as sedimentation, filtration, centrifugation and ion exchange (23); all this kind of separators can remove about 95% of amalgam, as specified in ISO standard number 11143 (24).

Materials and methods

To perform a systematic review of the literature have been chosen initially some appropriate "key words", to use in the scientific database, and then the inclusion and exclusion criteria, that each paper should have respected in order to be considered in this research.
The searches have been carried out in PubMed, Medline and Cochrane databases and the "key

Table 2 - Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Language: Italian and/or English	Other language
Papers from 2000 to 2017	Papers before 2000
Specific jobs about incoming and wastewater	Not specific jobs

Table 3 - Group A, Incoming Dental Unit Water.

Microbial contamination of dental unit water	Bacterial biofilm in dental unit waterlines	Disinfection protocols for dental unit waterlines
(1)"Legionella spp. in dental unit waterlines"	(2)"Developing an ecologically relevant heterogeneous biofilm model for dental-unit waterlines"	(5) "Decontamination of dental unit waterlines using disinfectants and filters"
(3) "Impact of a risk management plan on Legionella contamination of dental unit water"	(6) "Management of dental unit waterline biofilms in the 21st century"	(7) "Effect of different disinfection protocols on microbial and biofilm contamination of dental unit waterlines in community dental practices"
(4) "Molecular analysis for bacterial contamination in dental unit water lines"	(8) "Biofilm problems in dental unit water system and its practical control"	(13) "Effect of biocides on biofilm bacteria from dental unit waterlines"
(12) "Is water in dental units microbiologically safe?"	(9) "The role of manufacturers in reducing biofilms in dental chair waterlines"	(16) "Reducing bacterial counts in dental unit waterlines: tap water versus distilled water"
	(11) "Rechargeable biofilm-controlling tubing materials for use in dental unit waterlines"	

words" used were "incoming dental unit water" and "dental unit wastewater"; the criteria chosen concerned the language and the year of publication, in particular were considered papers of the last 17 years written in English and Italian, in order to have data as recent as possible and to ensure a proper understanding of the text. Also were not considered all jobs that deal the incoming and wastewater in a non specific way; this decision has been taken in order to have a specific and detailed review about the chosen topics (Table 2).

Results

In this revision were identified 21 papers that respected the inclusion and exclusion criteria selected; these were divided in two different groups depending of their topic: group A, 13 papers on the theme of incoming dental unit water; group B, 8 papers on the theme of dental unit wastewater.
In the group A, the incoming dental unit water's one, most jobs regarded the microbial contamination of dental unit water (1, 3, 4, 12), the dental unit bacterial biofilm (2, 6, 8, 9, 11) and the many disinfection protocols (5, 7, 13, 16) (Table 3).
Group B, that collect jobs about dental unit wastewater, is really scant, in fact there are only 8 works and all of them analyzed the problem of dental amalgam in wastewater (Table 4).

Discussion

The data obtained from this research show how today the scientific community focus their atten-

Table 4 - Group B, Dental Unit Wastewater.

(17) "Comparison of chlorine and chloramines in the release of mercury from dental amalgam"
(18) "Design and evaluation of a filter-based chairside amalgam separation system"
(19) "Effect of iodine on mercury concentrations in dental-unit wastewater"
(20) "Determination of methyl mercury in dental-unit wastewater"
(21) "The environmental effects of dental amalgam"
(22) "Laboratory evaluation of amalgam separators"
(23) "Amalgam waste management"

tion only on the problem of microbial dental unit water contamination and how to solve it.
Thanks to these scientific papers, today has been identified most of microbial agents located in dental unit water and, using specific filters and chemical disinfection systems, is possible to restrict this problem.
About dental unit wastewater, the only aspect that has been studied is the dental amalgam pollution.
Today dental amalgam, material used in the past for dental fillings, is considered toxic for the mercury that compose it; often in clinical practices dentists use this material, during placement and removal of amalgam restorations (23): for this reason the management of amalgam's waste is a current topic.
Worldwide environmental concerns over mercury pollution had led the United Nations Environmental Program (UNEP), in 2012, to draw up "the Minamata Convention", that recommends a phase-down of amalgam; the aim is to ban it in the future, preferably by 2030 (25).
In Italy, the "Ministero della Salute" published, in the January 2014, the "Raccomandazioni cliniche in Odontostomatologia", in which it's not recommended the use of this material but, at the same time, it isn't prohibited (26).
The amalgam environmental pollution is a current topic, but, about the dental unit wastewater, is reductive focusing the attention exclusively on this one, because there is a lot of other materials and drugs that could contaminate dental unit wastewater.
Recently, in 2013, the Italian "Corte di Cassazione Penale, sez III, sentenza 17 gennaio 2013, n°2340" expresses itself about this problem, bringing out a hole about dental unit wastewater regulation in the Italian law. In this sentence, in fact, dental unit wastewater is considered as industrial ones, unsuitable to be introduced in the urban sewer system like domestic waste; however there isn't specific law that regulates the dental unit wastewater removal.

Conclusion

In this review has been analyzed some recent scientific papers about the quality of dental unit wastewater, focusing the attention on the environmental problem.
No research has been found about the composition of dental unit wastewater, except for dental amalgam, in spite of the great number of materials used in dental practice and so easily introduced in dental unit waterlines. This gap, find in scientific literature, there is also in the legislature where, at the present time, there isn't specific law about dental unit wastewater.
This probably happens because of a lack of scientific proof demonstrating dental unit wastewater dangerous, that are introduced in the urban sewer system directly, without any kind of preventive measures.
However it's necessary to try the real environmental dangerousness of this wastewater and, at the same time, to establish specific laws for every dentist's surgery.

References

1. Sedlata Juraskova E, Sedlackova H, Janska J, Holy O, Lalova I. Legionela spp. in dental unit waterlines. Bratisl Lek Listy. 2017;118(5):310-14.
2. Lal S, Pearce M, Achilles-Day UE, Day JG, Morton LH, Crean SJ, Singhrao SK. Developing an ecologically relevant heterogeneous biofilm model for dental-unit waterlines. Biofouling. 2017 Jan;33(1):75-87.
3. Leoni E, Dallolio L, Stagni F, Sanna T, D'Alessandro G, Piana G. Impact of a risk management plan on Legionella contamination of dental unit water. Int J Environ Res Public Health. 2015;12(3):2344-58.
4. Watanabe A, Tamaki N, Matsuyama M, Kokequchi S. Molecular analysis for bacterial contamination in dental unit water lines. New Microbiol. 2016;39(2):143-5.
5. Monarca S, Garusi G, Gigola P, Sampinato L, Zani C, Sapelli PL. Decontamination of dental unit waterlines using disinfectants and filters. Minerva Stomatol. 2002;51(10):451-9.
6. O'Donnel MJ, Boyle MA, Russell RJ, Coleman DC. Management of dental unit waterline biofilms in the 21st century. Future Microbiol. 2011;6(10):1209-26.
7. Dallolio L, Scuderi A, Rini Ms, Valente S, Farruggia P. Effect of different disinfection protocols on microbial and biofilm contamination of dental unit waterlines in community dental practices. Int J Environ Res Public Health. 2014;11:2064-76.
8. Coleman DC, O'Donnell MJ, Shore AC, Russell RJ. Biofilm problems in dental unit water system and its practical control. J Appl Microbiology. 2009;106: 1424-37.
9. Coleman DC, O'Donnell MJ, Shore AC, Swan J, Russell RJ. The role of manufacturers in reducing biofilms in dental chair waterlines. J Dent. 2007;35(9):701-11.
10. Weinthal E, Parag Y, Vengosh A, Muti A, Kloppmann W. The EU drinking water directive; the boron standard and scientific uncertainty. Eur Env. 2005;15:1-12.
11. Luo J, Porteous N, Sun Y. Rechargeable biofilm-controlling tubing materials for use in dental unit waterlines. ACS applied materials & interfaces. 2011;3(8): 2895-903.
12. Michalkiewcz M, Ginter-Kramarczyk D, Kruszelnicka IK. Is water in dental units microbiologically safe? Medycyna Pracy. 2015;66(6):763-70.
13. Liaqat I, Sabri AN. Effect of biocides on biofilm bacteria from dental unit water lines. Curr Microbiol. 2008;56:619-24.
14. Kettering JD, Stephens JA, Muñoz-Viveros CA, Naylot WP. Reducing bacterial counts in dental unit waterlines: tap water versus distilled water. J Contemp Dent Pract. 2002;15;3(3):1-9.
15. Decreto Legislativo del 3 Aprile 2006 n°152.
16. Corte di Cassazione Penale, sez. III, sentenza 17 gennaio 2013, n°2340.
17. Stone ME, Scott JW, Schultz ST, Berry DL, Wilcoxon M, Piwoni M, Panno B, Bordson G. Comparison of chlorine and chloramines in the release of mercury from dental amalgam. Sci Total Environ. 2009;407 (2):770-5.
18. Stone ME, Cohen ME, Berry DL, Ragain JC Jr. Design and evaluation of a filter-based chairside amalgam separation system. Sci Total Environ. 2008;396(1):28-33.
19. Stone ME, Kuehne JC, Cohen ME, Talbott JL, Scott JW. Effect of iodine on mercury concentrations in dental-unit wastewater. Dent Mater. 2006;22(2):119-24.
20. Stone ME, Cohen ME, Liang L, Pang P. Determination of methyl mercury in dental-unit wastewater. Dent Mater. 2003;19(7):675-9.
21. Chin G, Chong J, Kluczewska A, Lau A, Gorjy S, Tennant M. The environmental effects of dental amalgam. Aust Dent J. 2000;45(4):246-9.
22. Fan PL. Batchu H, Chou HN, Gasparac W, Sandrik J, Meyer DM. Laboratory evaluation of amalgam separators. J Am Dent Assoc. 2002;133(5):577-84.
23. Jokstad A, Fan PL. Amalgam waste management. Int Dent Jour. 2006;56:147-153.
24. International Standard ISO 11143. Dental Equipment-Amalgam Separators; 1999. Geneva, Switzerland: International Organisation for Standardisation; 1999:1-23.
25. Bailey M. Minamata Convention on Mercury. United States Environmental Protection Agency. Retrived. 2014 October, 12.
26. Ministero della Salute, Dipartimento della sanità pubblica e dell'innovazione. Raccomandazioni Cliniche in Odontostomatologia. 2014 January.

Correspondence to:
Maria Elena Cataldi
Department of Clinical Sciences and Translational Medicine
University of Rome "Tor Vergata"
Rome, Italy
E-mail: melena.88@hotmail.it