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Physicochemical and Heavy Metals Analysis of Effluent Discharge of Metal Processing Industries

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Abstract: *Processing of metals have been increased greatly in recent years. As a result, quantities of waste material and pollutants have also increased. The present research work deals with the study of some of the important physicochemical and heavy metal parameters of Waste Water of Metal Processing Industries. In this study, like; physicochemical and heavy metal parameters PH, COD, BOD, TDS, TSS, DO, TOC, Oil and Grease percentage, Cd, Cr, Ni, Pb, Hg, Cu, Zn, Fe, Mg, Mn and bacterial and fungal species from wastewater samples were analyzed. The results of the physico-chemical analysis were obtained in the following range; pH (8.8-10.2), BOD (456.56-1931.48 mg/ L), COD (585.42-1967.51 mg/ L), TDS (23.34- 894.56 mg/L), TSS (63.67-243.45 mg /L), DO (7.3 – 13.5), Oil & grease (7.6 – 21.6 mg/l). The concentration of some metals (mg/L) in the samples analysed were found to be in the following range; Cd (0.32- 0.56), Cr (0.08- 4.56), Ni (0.32- 1.43), Pb(0.07- 0.41), Hg(0.06- 0.36),, Cu (0.23- 1.43), Zn (0.09- 0.27), Fe (0.37- 1.67), Mg (0.45- 1.12), Mn (0.23-0.58) and Total coliform count was >100. Some of the results were above the permissible limits set by World Health Organisation (WHO) most especially, effluent from metal processing Industry. It can be concluded that all the effluents required further treatment before releasing them into water body or land in other to prevent pollution.*

Keywords: *Physicochemical, Heavy Metals, Effluent and Metal Processing Industries*

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I. Introduction

The mining and metallurgical industries were known to be a source of toxic materials since ancient times. The Romans, for example, used to send convicts to work in mercury mines because it was known that they will die shortly from the air in the mine. Metal processing factories are the accessory units of many industries, along with the automobile industries, therefore, it is evident that the waste water from metal processing industries is definitely contributing to soil and water pollution problems.(Cheng, 2006), waste waters from these metal processing industries have permanent toxic effects on human and environment.(Rehman *et al.*, 2008). Cadmium is non-essential but poisonous for plants, animals and humans (Gupta and Gupta 1998). Nickel has been implicated as an embryo toxin and teratogen (Chen and Lin 1998). Thus, cadmium, chromium, copper, nickel, arsenic, lead and zinc are some of the major metals in waste waters of metal processing industries. Due to their high solubility in aquatic environment they are absorbed by living organisms, once they enter in food chain large concentrations may get accumulated in human body leading to serious health disorders (Babel and Kurniawan 2004).

All these chemical wastes are hazardous to plant, animal, human being also and techniques available for waste treatment are costly and not proper also.So, we have proposed to undertake the studies with the help of microorganisms. Microbiological techniques are efficient and also not very costly. There are some reports about the growth of microorganisms in waste water which contain heavy metal, oil and grease. So it is very easy to deal this waste with microorganism and use of microbiological techniques. In steel and Automobile industries metal working fluids (MWF) are used to optimize the process of machining operations such as turning, grinding, drilling, boring and milling. They flush away chips and metal fines from tools and workpieces, as well as acting as coolants and lubricants. (Muszynski and Lebkowska, 2005); Oily emulsions are common waste products of petrochemical metal and food processing industries (Coca *et al.*, 2011, Abdel-Raouf 2012); Due to the discharge of large amounts of metal contaminated wastewater, industries bearing heavy metals, such as Cd, Cr, Cu, Ni, As, Pb and Zn are the most hazardous among the chemical intensive industries. Because of their high solubility in the aquatic environments, heavy metals can be absorbed by living organism. Once they enter the food chain, large concentrations of heavy metals may accumulate in human body. If the metals are ingested beyond the permitted concentration, they can cause serious health disorders. (Babel and Kurniwan, 2004) The pollution of the environment with toxic heavy metals is spreading throughout the world along with industrial progress micro-organisms and microbial products can be highly efficient bioaccumulators of soluble and particulate forms of metals especially dilute external solutions. Microbe related technologies may provide an alternative or addition to conventional method of metal removal or metal recovery(C. Edward Raja, G.S. Selvam, and Kiyoshi Omine 2009). Therefore, there is an urgent need for the treatment of metal processing industry waste. Waste management strategies adopted in India have failed to keep pace with the industrial growth and urbanization. Physicochemical analysis of the waste water for important parameters, take colour, $_{P}$H, COD, BOD, TDS, TSS, DO, TOC, Oil and Grease percentage, microbial analysis, Cd, Cr, Ni, Pb, Hg, Cu, Zn, Fe, Mg, Mn was carried out.

II. Materials And Methods

Collection of Effluent Samples: The sampling was carried out in January, 2019. The sampling site in the present study was a metal processing industry in the Marathwada region. Samples were collected from the different sites of the selected area in a wide mouth polyethylene bottle. One portion of each effluent sample was immediately preserved with concentrated nitric acid for heavy metal analysis. After acidification the samples were stored at 4^{o} C in refrigerator to prevent change in volume due to evaporation.

Chemicals: All the chemicals used in the study were of analytical grade and were procured from Merck (Mumbai, India).

Sample Analysis: Physico- chemical parameters of biochemical oxygen demand (BOD), total dissolved solid (TDS), pH, dissolved oxygen (DO), total hardness, chloride, sulphate, nitrate, phosphate, chemical oxygen demand and alkalinity were measured in triplicate. pH was measured in situ using a pH meter. Dissolved oxygen, alkalinity, sulphate, nitrate, phosphate, chloride and total hardness were determined by titration (Boyd, 1981). Total Dissolved Solids (TDS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) was determined sequel to APHA (2005).Analysis of different metal ions in the effluent samples was determined by Atomic Absorption Spectrophotometer as per the standard methods (APHA, 2005, Kamaruzzaman*et al.*, 2011: Rahman *et al.*, (2012). Total coliform count was determined by MPN method (WHO, 1989).

III. Results and Discussion

In the present study, effluent samplesfrom metal processing industry were collected each month between January 2019-June 2019. The physicochemical parameters of the effluents were analyzed (Table 1).

Color: The result of the study revealed that colour of the untreated effluent was brownish in colour with offensive odour. A large number of pollutants can impart colour, taste and odour to the receiving water, thereby making them unaesthetic and unfit for domestic consumption (Jamal *et al.*, 2011). The colour of the effluent might be due to the presence of high amount of inorganic chemicals like sodium and chromium used during the processing of metal.

pH:

The pH of the samples ranged from 8.8-10.2 so presented in Table-1. Sample SR1 has the lowest (8.8), while sample B has the highest pH value of 10.35. All the pH values were within the permissible limits for industrial effluents set by WHO except sample SR3 and SR5. The pH of samples SR1, SR2, SR4 and SR6 are below the permissible standard for drinking water set by W.H.O while the pH of sample SR3 and SR5 was found to be above the standard.

Total suspended solids TSS: The TSS values (Table-1) of the samples ranged from 63.67- 243.45 mg /L. WHO standard for TSS is 10 mg/l. So it is clear that all the samples have very high TSS values which may be due to the fact that the waste contains many suspended particle. The maximum value of TSS (63.67- 243.45 mg /L) was recorded in the effluent of sample SR3 and SR5. Effluents of such high TSS may cause handling problem, if directly applied to agricultural field, or if this effluent is discharged to river or stream, it will make it unsuitable for aquatic life. Literature classified wastewater TSS as follows: TSS < 100 mg/l as weak, TSS > 100 mg/l as but < 220 mg/l as medium and TSS > 220 mg/l as strong wastewater. Therefore, waste water from SR3 and SR6 is strong and cannot be discharged into stream.

Total dissolved solids TDS: The TDS values of the samples ranged from 23.34- 894.56 mg/L (Table-1). The lowest value was found in sample SR2 while the highest value was found in sample SR5 and SR6. The WHO standard for TDS is 500 mg L^{-1}. The samples SR5 and SR6 not have values within the permissible limit, where as SR2, SR3and SR4 are within permissible limit as per WHO standard. High TDS is caused by high solids loading.

Biological and Chemical oxygen demand BOD & COD:

An indication of organic oxygen demand content of wastewater can be obtained by measuring the amount of oxygen required for its stabilization either as BOD and COD. Biological Oxygen demand (BOD) is the measure of the oxygen required by microorganisms whilst breaking down organic matter. While Chemical Oxygen Demand (COD) is the measure of amount of oxygen required by both potassium dichromate and concentrated sulphuric acid to breakdown both organic and inorganic matters The BOD values ranged from 456.56-1931.48 mg/ L as presented in Table-1. The COD values ranged from 585.42-1967.51 mg/. Sample SR2 has the lowest BOD and COD while sample remaining are having the highest BOD and COD. These effluents on entering fresh water (rivers, stream etc) make the O_2 depleted, causing suffocationof fish and other aquatic fauna and flora resulting in the death of aquatic life. The concentrations of BOD and COD in all the samples were higher than the WHO values of 50 mg/l for the discharged of wastewater into stream. High COD and BOD concentration observed in the wastewater might be due to the use of chemicals, which are organic or inorganic that are oxygen demand in nature.

Oil and Grease

Oil and grease if present in excess amount it interfere with aerobic and anaerobic biological process. The all samples contain high quantity of oil and grease which causes serious problems. The average value of oil and grease was 21.6mg/L which is higher than the recommendations of WHO (2003). Akan et al. (2008) showed comparatively less value as 680mg/L in untreated effluent. Trivedi et al., (1986) reported oil and grease in textile industry effluent varies from 230 to 1897 mg/L.

Heavy metals:

Investigated metals in the industrial effluents of various industries are presented in Table-2. The composition of metals in the wastewater samplesranged from Cd (0.32- 0.56), Cr (0.08- 4.56), Ni (0.32- 1.43), Pb(0.07- 0.41), Hg(0.06- 0.36),, Cu (0.23- 1.43), Zn (0.09- 0.27), Fe (0.37- 1.67), Mg (0.45- 1.12), Mn (0.23- 0.58). The concentrations of metals in the samples analysed are in the following order Mg>CD>Mn>Ni>Mn>CuZn>Cr>Hg>Pb. While Mg can improve crop yield, only trace amount of Zn is required but, Pb and Cd are toxic. Highest amount of all the heavy metals analysed were found in sample D while, the lowest amount of Cd and Pb were found in sample A. The concentration of heavy metals (Pb, Cd and Zn) in all the samples analysed were far above the maximum permissible level recommended by WHO

Table 1. Physico-Chemical analysis of Effluent Samples Collected from different Metal processing Industries

Sample	Colour	pH	BOD (mg/L))	COD (mg/L	TDS(mg/L)	TSS(mg/L)	DO (ppm)	Oil & Grease (mg/L)	T.coliform (MPN/100ml)
SR1	Brown	9.2	1726.52	1585.30	584.83	167.34	10.2	17.3	86
SR2	Clear	8.8	456.56	585.42	23.34	75.34	6.8	7.6	40
SR3	Dark	10.1	1852.23	1886.62	495.35	243.45	13.5	21.6	170
SR4	Gray	8.10	787.73	678.93	31.27	63.67	7.3	12.4	63
SR5	Dark	10.2	1931.48	1931.48	894.56	189.45	12.6	20.8	480
SR6	Brown	9.4	1811.56	1774.19	765.98	211.39	9.78	13.6	210
WHO Standard	Clear	6.5 – 9.2	00	20.00	500	10.00	NS	NS	Zero

Table 2. Metal ions (mg/L) present in effluent at various sites (mean of 3 analysis) from different Metal processing Industries

Sample	Cd	Cr	Ni	Pb	Hg	Cu	Zn	Fe	Mg	Mn
SR1	0.35	0.17	0.62	0.26	0.06	0.63	0.13	0.58	0.98	0.23
SR2	0.43	2.34	0.32	0.16	0.12	0.78	0.07	1.41	1.12	0.41
SR3	0.32	4.56	1.24	0.07	0.06	1.17	0.11	1.27	0.68	0.21
SR4	0.27	0.08	0.86	0.17	0.13	0.38	0.09	1.67	0.77	0.58
SR5	0.56	5.67	1.32	0.34	0.23	1.43	0.27	0.78	0.45	0.36
SR6	0.73	1.43	1.43	0.41	0.36	0.23	0.12	0.37	0.85	0.17
WHO Standard	0.003	0.05	0.02	0.05	0.001	0.10	<1.0	1.00	0.05	0.5

The sample SR3 and SR 6 was found more polluted than other sites. Wastewater discharge from metal processing industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem. The presence of oil and grease in an effluent was mainly due to the processing operations. It should be removed since they usually float and affect the oxygen transfer to the water and also objectionable from an aesthetic point of view.

Microbial Analysis: The wastewater contained a large number of bacteria and fungal count is given in Table 3. Total count the quantitative idea about the presence of microorganisms such as bacteria, yeast and mold in a sample was recorded using total viable count (TVC) which represents the number of colonies forming units (CFU) per g (or per ml) of the sample.

The bacteriological assessment of effluents from metal processing industries reveals the presence of bacterial contaminants and this is in agreement with the findings of (Mohapatra, 2008; Morley,2007).There is a greater risk to public health from microbes that is associated with wastewater consumption that is contaminated with human and animal excreta. Hence wastewater can be faecally contaminated and can contain a variety of intestinal pathogens which cause diseases ranging from mild gastro- enteritis to the serious dysentery, cholera and typhoid. The most predominant waterborne disease, diarrhea has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths every year (Paul and Clark, 1989; Najafpour et al., 2008) These sources of bacterial contamination include surface runoff, pasture and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks and sewage treatment facilities (WHO,1989).

The waste discharged from metal processing industries is degradable waste, though it is hazardous to microorganism in the costal water. The extent of pollution was high as expressed by physicochemical properties. Analysis of industrial effluent discharge showed that the various parameters are beyond the permissible limit. The effluent from two industries shows acidic pH while remaining samples have alkaline pH. These values are generally due to the decomposition of the proteinaceous matter and emission of ammonia

Table 3. Microbial analysis of Effluent Samples Collected from different Metal processing Industries

Sample	Total viable bacteria count (CFU g-1)	Total viable fungi count (CFU g-1)
SR1	$5.43 X 10^5$	$4.76 X 10^3$
SR2	$4.78 X 10^7$	$5.23 X 10^3$
SR3	$6.54 X 10^6$	$4.64 X 10^4$
SR4	$4.45 X 10^5$	$3.23 X 10^3$
SR5	$8.78 X 10^7$	$4.75X 10^3$
SR6	$7.34 X 10^6$	$5.64 X 10^4$

IV. Conclusion

Heavy metals and Elements from the sampled wastewater analyzed, were found to be present in quantities not withinthe recommended safe limits as set by the World Health Organisation (WHO). this was obviously due to the use of various metals and its discharge in the water bodies from the metal processing industries. Overall findings indicated that effluent discharge of fish processing industries in Marathwada region is highly polluted and remedial steps should be to be taken for avoiding water pollution.

References

[1]. Abdel-Raouf E.M. 2012. Crude Oil Emulsions - Composition Stability and Characterization. Croatia: InTech.

[2]. Akan JC, Abdulrahman FI, Dimari GA, Ogugbuaja VO, 2008. Physicochemical determination of pollutants in wastewater and vegetable samples along the Jakara wastewater channelin kano metropolis, kano state, Nigeria. European Journal of Scientific Research, 23 (1): 122-133.

[3]. Apina, V. 1999. Agriculture's Influence on Water Quality in Lower Northeastern Thailand. In Proceedings of the Regional Workshop on Water Quality Management and Control of Water Pollution in Asia and the Pacific, Bangkok, 175-180 pp.

[4]. Bakalova S., Doycheva A., Ivanova I., Groudeva V., Dimkov R. 2007. Bacterial microflora of contaminated metalworking fluids. Biotechnol. &Biotechnol. Eq., 21(4), 437-441.

[5]. Bakalova S., Mincheva V., Doycheva A., Groudeva V., Dimkov R. 2008. Microbial toxicity of ethanoloamines. Biotechnol&Biotechnol Eq., 22(2), 716-720.

[6]. Cheng C., Phipps D., Alkhaddar R.M. 2005. Treatment of spent metalworking fluids. Water Res., 39, 4051-4063.

[7]. Coca J., Gutierrez G., Benito J.M. 2011. Treatment of oily wastewater. [In:] Water Purification and Management, J. Coca-Prados, G. Gutierrez-Cervello (Eds.), NATO Science for Peace and Security Series - C: Environmental Security, Dordrecht: Springer.

[8]. da Silva E.J., Bianchi E.C., de Aguiar P.R. 2001. A Review of grinding fluids – performances and management. Revista de Ciencia&Technologia, 8(18), 67-77.

[9]. Effluent Limitations Guidelines and New Source Performance Standards for the Metal Products and Machinery Point Source Category; Final Rule. Part II. 2003. U.S. Environmental Protection Agency, Rules and Regulations, Federal Register, 68(92), 25685-25745.

[10]. Geier J., Lessmann H. 2006. Metalworking fluids. [In:] Contact dermaitis. 3rd edition, P.J. Frosch, T. Menne, J-P. Lepoittevin (Eds.), Berlin Heidelberg: Springer.

[11]. Gerulova K., Mihalkova A., Sergovicova M., Guoth A., Nadasska Z. 2011. Exotoxicity and biodegradability assessment of metalworking fluids by activated sludge bacteria. Research Papers: Faculty of Materials Science and Technology in Trnava, 19(31), 45-56.

[12]. Gilbert Y., Veillette M., Duchaine C. 2010. Metalworking fluids biodiversity characterization. J. Appl. Microbiol., 108(2), 437-449.

[13]. Grijalbo L., Fernandez-Pascual M., Garcia-Seco D., Gutierrez-Manero F.J., Lucas J.A. 2013. Spent metal working fluids produced alterations on photosynthetic parameters and cell-ultrastructure of leaves and roots of maize plants. J. Hazard. Mater., 260, 220-230.
[14]. Jamal, M., Dawood, S., Nausheenawood, S.,Ilango, B.K. 2011. Characterization of tannery effluent. *J. Ind. Pollut. Control*, 20: 16.
[15]. Kaszycki P., Pawlik M., Petryszak P., Kołoczek H. 2010. Aerobic process for in situ bioremediation of petroleum-derived contamination of soil: a field study based on laboratory microcosm tests. Ecol. Chem. Eng. A, 17(4-5), 405-414.
[16]. Kaszycki P., Petryszak P., Pawlik M., Kołoczek H. 2011. *Ex situ* bioremediation of soil polluted with oily waste: use of specialized microbial consortia for process bioaugmentation. Ecol. Chem. Eng. S, 18(1), 83-92.
[17]. Kaszycki P., Szumilas P., Kołoczek H. 2001. Biopreparatprzeznaczony do likwidacjiśrodowiskowychskażeńwęglowodoramii ich pochodnymi. Inż. Ekol., 4, 15–22.
[18]. Kołoczek H., Kaszycki P. 2006. Bioremediacjazanieczyszczeńrafineryjnych w środowiskugruntowo-wodnym. [In:] Metodyusuwaniazanieczyszczeńwęglowodorowych ze środowiskagruntowo-wodnego (Methods of hydrocarbon contaminants removal from ground-water environment), S. Rychlicki (Ed.), UczelnianeWyd. Nauk.-Dydakt., AGH, Kraków.
[19]. Lazarević F.B., Krstić I.M., Lazić M.L., Savić D.S., Skala D.U., Vejlković V.B. 2013. Scaling up the chemical treatment of spent oil-in-water emulsions from non-ferrous metal-processing plant. Hem. Ind., 67(1), 59-68.
[20]. Liu H-M., Lin Y-H., Tsai M-Y., Lin W-H. 2010. Occurrence and characterization of culturable bacteria and fungi in metalworking environments. Aerobiologia, 26, 339-350.
[21]. MacAdam J., Ozgencil H., Autin O., Pidou M., Temple C., Parsons S., Jefferson B. 2012. Incorporating biodegradation and advanced oxidation processes in the treatment of spent metalworking fluids. Environ. Technol., 33(24), 2741-2750.
[22]. Mattsby-Baltzer I., Sandin M., Ahlström B., Allenmark S., Edebo M., Falsen E. 1989. Microbial growth and accumulation in industrial metal-working fluids. Appl. Environ. Microbiol., 55, 2681-2689.
[23]. Mirer F.E. 2010. New Evidence on the Health Hazards and Control of Metalworking Fluids Since Completion of the OSHA Advisory Committee Report. Am. J. Ind. Med., 53(8), 792-801.
[24]. Mohapatra, P.K. 2008. Textbook of Environmental Microbiology. New Delhi, India, IK International Publishing House.
[25]. Morley, N.J. 2007. Anthropogenic effects of reservoir construction on the parasite fauna of aquatic wildlife. EcoHealth, 4(4): 374-383.
[26]. Najafpour, Sh., Alkarkhi, A.F.M., Kadir, M.O.A. and Najafpour, Gh.D. 2008. Evaluation of Spatial and Temporal Variation in River Water Quality. International Journal of Environmental Research, 2(4): 349-358.
[27]. Paul, E.A. and Clark, F.E. 1989. Soil Microbiology and Biochemistry. 3rd Edition, San Diego: Academic Press.
[28]. Prescott, W.J. 2008. Harley, and Klein's Microbiology-7th international Edition./Joanne M. Willey, Linda M. Sherwood, Christopher J. Woolverton. New York [etc.]: McGraw- Hill Higher Education, 695 pp.
[29]. Rabenstein A., Koch T., Remesch M., Brinksmeier E., Kuever J. 2009. Microbial degradation of water miscible metal working fluids. Int. Biodeter. Biodegr., 63(8), 1023-1029.
[30]. Saha R., Donofrio R.S. 2012. Microbiology of metalworking fluids. Appl. Microbiol. Biotechnol., 92, 1119-1130.
[31]. Selvaraju S.B., Khan I.U.H., Yadav J.S. 2008. Specific detection and quantification of culturable and non-culturable mycobacteria in metalworking fluids by fluorescence-based methods. Lett. Appl. Microbiol., 47(5), 451-456.
[32]. Theaker D., Thompson I. 2010. The industrial consequences of microbial deterioration of metal working fluid. [In:] Handbook of hydrocarbon and lipid microbiology, K.N. Timmis (Ed.), Berlin Heidelberg: Springer-Verlag.
[33]. Tillie-Leblond I., Grennouillet F., Reboux G., Roussel S., Chouraki B., Lothois C., Dalphin J-C., Wallaert B., Millon L. 2011. Hypersensitivity pneumonitis and metalworking fluids contaminated by mycobacteria. Eur. Respir. J., 37, 640-647.
[34]. Trafny E.A. 2013. Microorganisms in metalworking fluids: current issues in research and management. Int. J. Occup. Med. Environ. Health., 26(1), 4-15.
[35]. Trivedi, RK and Goel PK, 1984. Chemical and biological methods for water pollution studies Karad Environmental Publication. pp. 1-251.
[36]. Van der Gast C.J., Whiteley A.S., Lilley A.K., Knowles C.J., Thompson I.P. 2003. Bacterial community structure and function in a metal-working fluid. Environ. Microbiol., 5(6), 453-461.
[37]. Veillette M., Thorne P.S., Gordon T., Duchaine C. 2004. Six month tracking of microbial growth in a metalworking fluid after system cleaning and recharging. Ann. Occup. Hyg., 48, 541-546.
[38]. Wang H., Reponen T., Lee S.A., White E., Grinshpun S.A. 2007. Size distribution of airborne mist and endotoxin-containing particles in metalworking fluid environments. J. Occup. Environ. Hyg., 4(3), 157-165.
[39]. WHO. 2008. Geneva Guidelines for drinking-water quality (electronic resource). 3rd Edition, incorporating (1st and 2nd agenda), Recommendations.
[40]. Windelspecht, M. 2003. Groundbreaking scientific experiments, inventions, and discoveries of the 19th century. Greenwood Publishing Group, 33 pp.
[41]. World Health Organisation. 2003. Chloride in Drinking Water, Background Document for Preparation of WHO Guidelines for Drinking-Water Quality, World Health Organization, Geneva, Switzerland.
[42]. World Health Organisation. 2014. Water and Sanitation: Protection of the Human Environment. World Health Organisation, Geneva, Switzerland.
[43]. World Health Organization. 1989. Health guidelines for the use of wastewater in agriculture and aquaculture. Report of World Health Organization Press, Geneva, Switzerland.
[44]. World Health Organization. 1993. Guideline of drinking water quality. Health Criteria and Other Supporting Information. WHO, Geneva, Switzerland, 162 pp.

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