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ANTIBIOTIC APPLICATIONS IN FISH FARMS AND ENVIRONMENTAL PROBLEMS

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ABSTRACT
Today, fish farming creates significant impacts on water resources and food chain from a global perspective, as compared to those of the other agricultural activities. Some methods and chemicals heavily using production and consumption periods in fish farming are related to the environmental damages. Chemicals have a common usage in both the world and our country to protect the products from the negative effects of diseases. They are also imposed to increase the production. As Turkey has significant potential in fish farming in comparison to many other countries in the world, there is a wide use of antibiotics in production. This research examines the use of antibiotics in fish farming to shed light on the effects of chemicals on the production and human health.

Keywords: *Antibiotic, Fish Farming, Environmental Factor, Aquaculture*

1. INTRODUCTION

Environmental pollution is defined as the deterioration of the natural balance of the ecosystem by various pollutants emerging as a result of human activities (Karaman, 2006). Therefore, in order to be able to eradicate the pollution, scientific studies are being carried out at the international level (Orçun and Sunlu, 2007). Scientific studies on this issue investigate the imbalance related to the ecology in different ways and suggest solutions (Karaman, 2006). In particular, fish farms need to be monitored in terms of unconscious and irregular chemical usage (drugs and antibiotics, disinfectants etc.) and in parallel with this, in terms of formation of environmental pollution. Antibiotics are substances produced by microorganisms that can destroy or inhibit the growth of other microorganisms. At the present time, antibiotics are not only used as a drug for humans. It is also broadly used in livestock breeding and fish farming. Some of the microorganisms that cause health problems in fish farms include *Mycobacterium marinum, Nocardia spp., Edwardsiella tarda, Vibrio vulnificus, Vibrio vulnificus, Vibrio parahaemolyticus, Streptococcus iniae, Lactococcus garviae, Micrococcus lylae, Aeromonas hydrophila, Plesiomonas shigelloides, Erysipelotrix insidiosa, Escherichia coli, Salmonella spp., Raoultella ornithinolytica, Pseudomonas spp., Leptospira icterohaemorrhagiae, Yersinia ruckerii and Stenotrophomonas maltophilia* (Türk, 2015). Antibiotics used for health and development in fish farms can kill beneficial microorganisms in the receiving environment. In addition, the application of antibiotics in fish farms leads to the proliferation of antibiotic-resistant microorganisms. It is generally known that 20-30% of antibiotics are in the body of fish, and the remaining 70-80% are transmitted to the environment. However, antibiotics that are recklessly discharged into the medium pose a major danger to habitats and all living things (Zhong *et al.*, 2018; Uma and Rebecca, 2018; Yang *et al.*, 2018; Li *et al.*, 2018; Tran *et al.*, 2016; Martinez *et al.*, 2015; Bengtsson-Palme and Larsson, 2015; Van Boeckel *et al.*, 2015). Anthropogenic activities result in the input of different antibiotics into aquatic environments, including effluent from hospitals and wastewater treatment facilities and discharge from agriculture, fish farming, and livestock husbandry (see Fig. 1) (Yang *et al.*, 2018; Guo *et al.*, 2017; Mishra *et al.*, 2017). Today, some factors such as the rapid increase of food demand in parallel with the increasing population, socio-economic progress and the efforts to reach healthy food led to the numerical development of fish and similar species having economic values (Meador *et al.*, 2016; Scott *et al.*, 2015).

Aquaculture is an effective food production area in terms of reducing the unconscious fishing in the natural fishery, creating business space and supporting the economy. Aquaculture has become an important food source with the increase of the global population (Miranda *et al.*, 2018). Fish farming industries play a crucial role in profit and employment in worldwide and procuration reliable foods to the population of the countries (Rahman *et al.*, 2017). The value of fish produced in fish farms has increased steadily in the last four decades (see Fig. 2) (Elevancini, 2017). For these reasons, aquaculture tends to increasingly grow all over the world and in Turkey. Compared to other countries, aquaculture activities in fish farms in Turkey are quite new (see Table 1) (Aydın and Baltacı, 2017; Özdal and Pulatsü, 2012).

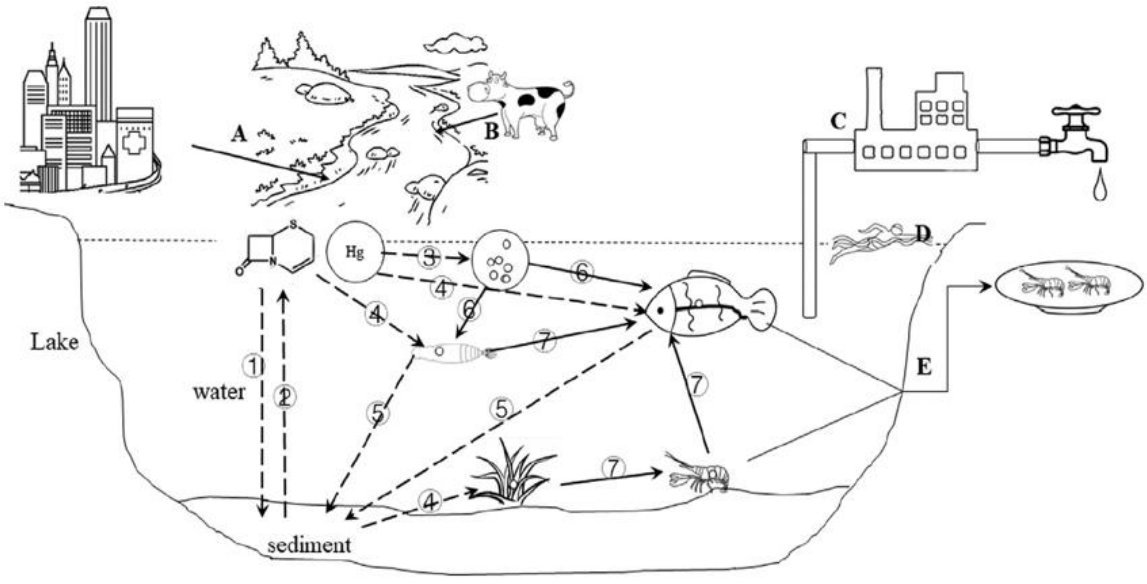

Fig. 1. Spread of antibiotics in different environments and possible exposure to all live health (Yang *et al.*, 2017a; Yang *et al.*, 2017b). *(A: antibiotics from wastewater treatment facilities-hospitals; B: antibiotics from agriculture, aquaculture and livestock husbandry; C: drinking water; D: recreation and swimming; E: swallow of aquatic products. ① the precipitation of antibiotics from water; ② the resuspension of antibiotics from residue; ③ change of microbial community by antibiotics; ④ chemical drugs cumulative by the aquatic medium; ⑤ antibiotics released from the death of aquatic lives; ⑥ Antibiotics absorbed/ adsorbed by water biota; ⑦ the transport of antibiotics and drugs among aquatic biota)*

Tablo 1. According to the year in Turkey, the amount of product produced in fish farms (Kayhan and Olmez, 2014).

Fish species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Total (tonnes)	138773	151990	158640	166801	188785	212410	233394	233713	238638	250281
Fish farms in the inland water district										
Trout (Rainbow)	58433	65928	75657	78165	100239	111335	122873	107533	100411	99712
Mirror-carp	600	629	591	403	207	222	146	157	206	196
Sturgeon	-	-	-	-	-	-	-	17	28	6
Tilapia	-	-	-	-	-	-	-	32	12	58
Fish farms in the sea area										
Trout (Rainbow)	2740	2721	5229	7079	7697	3234	5186	4812	6 187	4643
gilt-head bream	33500	31670	28362	28157	32187	30743	35701	41873	51844	58254
Perch	41900	49270	46554	50796	47013	65512	67913	74653	75164	80847
Fangri	-	-	-	-	-	-	-	106	143	225
Granyöz	-	-	-	-	-	-	-	3281	2801	2463
Sinagrit	-	-	-	-	-	-	-	113	132	43
tunny	-	-	-	-	-	-	-	1136	1710	3834
Other	1600	1772	2247	2201	1442	1364	1575	-	-	-

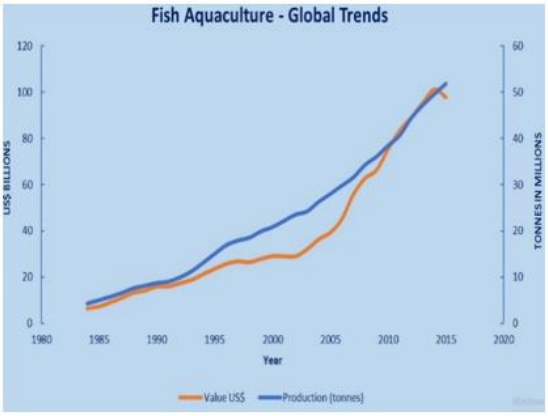

Fig. 2. Global production and value of cultured fish for the period 1984-2015 (Elevancini, 2017).

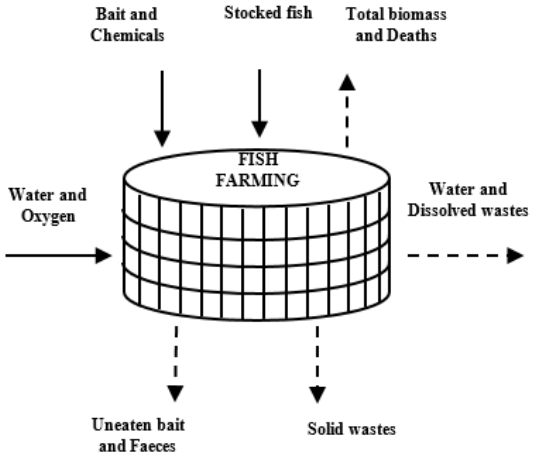

Fig. 3. Main inputs (straight lines) and output (cut lines) from cages in fish farms (URL-1, 2018).

Due to the faeces and non-consumed feed, food elements in various forms (organic carbon, nitrogen, phosphorus) enter the receiving environments in the fish farms (Topçu *et al.*, 2017; Yavuzcan *et al.*, 2010). In addition, the antibiotic and drug residues used to protect fish and aquatic products from diseases also enter the receiving environments (Agoba *et al.*, 2017; Kim *et al.*, 2017; Caruso, 2016; Meador *et al.*, 2016; Scott *et al.*, 2015;). These chemicals accumulating in the base of the cage systems of these farms cause adverse changes in the life on the seabed, and therefore, they form sensitive areas in terms of environmental pollution. The production-environment interaction needs to be evaluated in order to determine whether the aquaculture in net cages used in the fish farms cause pollution of water resources. Fig. 3 shows the components that should be in a cage system used in these farms. The environmental problems occurring in fish farms during the aquaculture works are graphically expressed.

In this study, the environmental effects of production of various fish and other aquatic products carried out in cage systems in fish farms on especially water ecosystem, sediment, benthic flora and fauna, the harmful aspects of antibiotics and other drugs used to destroy pathogenic microorganisms and the problems that might occur in the food chain were investigated.

2. MATERIAL AND METHOD

All academic areas related to fish farms and antibiotic usage were determined by electronic scanning of MEDLINE, PubMed, Google academic, ISIWeb of Science, Springer, Taylor-Francis, Elsevier and Scopus without time and language limitations. By using some keywords (fish farms, antibiotics, environmental problems, feed, cage fishing etc.), a national and international literature review was carried out.

3. ENVIRONMENTAL EFFECTS OF FISH FARMS

Although the rapid development of fish farms provides important socio-economic contributions to the countries, particularly their negative effects on water quality and ecological structure arise concern. Depending on the production methods and technologies in the farms, the amount of water products produced, and the quality of the receiving water environment, the size of this environmental change on the ecosystem varies.

3.1. Solid wastes and antibiotics

The negative effect of fish farming in cages on water resources emerges mainly due to the wastes originating from the aquaculture (Meador *et al.,* 2016; Abu Bakar *et al.,* 2016; Scott *et al.,* 2015). The types of waste originating from farms established in the receiving water environment have similar features all over the world, and the characteristics and levels of waste differ only according to the type of aquatic products and the farming technique (Yayan, 2015). Pollutants occurring as a result of the production of aquatic products in fish farms are considered as two different groups. The majority of solid wastes originating from fish farming is composed of substances such as fish faeces, scales, mucus secretion and non-consumed feed (see Fig. 4).

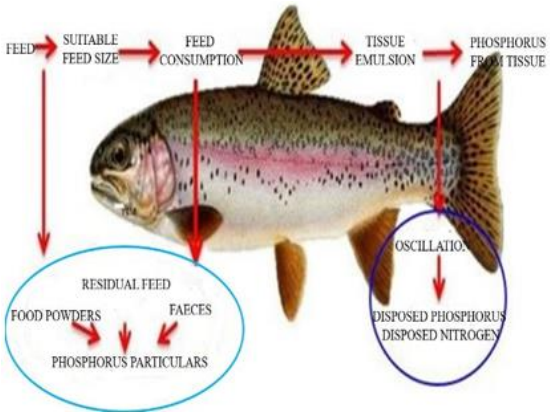

Fig. 4. Contaminants originating from a fish species produced in fish farms (Yayan, 2015; Rein *et al.,* 2015).

The highest rate of environmental pollutants in fish farms belongs to the pollutants resulting from feeding. At this point, it is observed that in the farms where proper feeding is not applied, there is a sediment accumulation and therefore an increase in the organic load of water (Yayan, 2015; Rein *et al.,* 2015; Yeo *et al.,* 2004; Bureau *et al.,* 2003). Solid wastes that are exposed in fish farms negatively affect the physicochemical structure and biological equilibrium of the different waters (Kim *et al.,* 2018; Opiyo *et al.,* 2018; Schumann *et al.,* 2017; Dolan *et al.,* 2013; Mirzoyan *et al.,* 2010). These solid wastes consist of various antibiotics, medicines, and uneaten fish food mixed with disinfectant, faeces, dead fish excretion and bio-flora. In particular, Tetracycline and amoxicillin are intensively applied with the aim of protecting the health of the fish (Chen *et al.,* 2017). Continuous exposure to these antibiotics in aquaculture may increase high antibiotic resistance (Zhao *et al.,* 2017; Harnisz *et al.,* 2015; Di Cesare *et al.,* 2013). Studies have reported that solid waste from fish farmings can act as potential pollutant-containing antibiotics (Kim *et al.,* 2018; Chen *et al.,* 2018; Xiong *et al.,* 2015; Luo *et al.,* 2010).

Antibiotics, drugs and hormones are extensively used in fish farms in order to treat the diseases caused by microorganisms such as *Clostridium, Vibrio, Pseudomonas, Escherichia, and Salmonella*, to enhance resistance, to improve product quality and for the other purposes (Cengizler *et al.,* 2017; Türk and Oğuz, 2013; Neary *et al.,* 2008;). In particular, various behavioural changes observed in fish (period movement, drowsiness, gathering together, etc.) and changes in the appearance of the eye (eye bleeding, colour problem, swelling, cysts, etc.) increase the use of these chemicals intensively. Especially, some antibiotics are used in the fish farms in all regions of the world (see Table 2) (Baba, 2017; Türk and Oğuz, 2013). In fish farms, *sodium, baylucite, iodophors, oxytetracycline, amoxicillin, erythromycin, sulphonamides* are widely used both in the world and in our country.

Table 2. Some chemicals used in fish farms (Kumar and Roy, 2017).

Antibiotics	Other Drugs	Disinfectants
Florfenicol	Akinitrazol	Phenols
Bacitracin	Methyl Parathion	Zephirol
Chloramphenicol	Salicylic acid	Sodium
Enrofloxacin	Copper sulphate	Baylusit
Canamycin	Trypaflavin	Formalin
Erythromycin	Rivanol	Chloramine T
Griseofulvin	Piavetrin	Slaked lime
Oleandomycin	Niclosamid	Quicklime
Neomycin	Metrifonate	Iodophors
Oxytetracycline	Lysol	Gonadotropin
Polymyxin	Gabrocol	Ormetoprim
Sulfamerazine	Diflubenzuron	Sulfasol
Sulfanilamide	Malathion	
Amoxicillin		

3.2. Effects on water quality criteria

In the cage where fish and other aqueous products are kept at fish farms, the effects of wastes originating from different production on aqueous environment have been being frequently observed in recent years. In particular, some studies have found that nitrogen, phosphorus, organic substance, chlorophyll-a, antibiotic residues, trace elements and suspended solids in the aqueous ecosystem increase the amount of solids, and reduce the entry of sunlight into the water, oxygen levels and acid-base balance. When the organic substance entering the aqueous environment by feed dissolves in water or transfers from sediment to water, it can lead to eutrophication and reduce the permeability of light especially in the environments where nutrients are limiter (see Fig. 5) (Coldebella et al., 2018; Abu Bakar *et al.,* 2016; Mancuso, 2015; Kayhan and Ölmez, 2014; Koca *et al.,* 2011; Holmer, 2010; Yıldırım and Korkut, 2004**;**).

4. CONCLUSIONS

While the world population is growing rapidly, humans' need for food, especially the need for animal source food is also increasing. In line with this food demand, fish farms have become one of the rapidly growing food sectors on the global scale. Together with the development of the aquaculture field, the increase of pollution problems in the ecosystem has become inevitable. Because of the chemicals used in this sector such as antibiotics, hormones, and drugs, important environmental problems have been observed in terms of the quality of receiving water, sediment and benthic ecosystem. As in the entire in pollution situation, a

strategy and plan for the pollution related to the fish farms also need to be developed. During the establishing and operating the fish farms, keeping certain precautions and rules in the foreground is of great importance to minimize the environmental pollution. In this context, the environmental aspects of aquaculture can be assessed in all aspects in the light of the following items.

1. In the selection of the area where the farms will be established, places with high flow rates should be preferred instead of places with low flow rates.
2. In the appropriate areas, at the end of each production season, the location of the cages should be changed; that is, the rotation should be applied.
3. In fish farms, feed management must be provided separately for each aquatic product and in this way, solid waste control must be ensured.
4. Because of some conditions (temperature-flow rate changes, insufficient gap rates in cages, water quality parameters) that can be observed in the areas established in fish farms, there may be uneasiness and restless behaviors in fish and similar aquatic products. In order to eliminate the existing stress, the regular control of the cage systems should be ensured.
5. Environmental monitoring of fish farms should be performed. In this way, detection of the problems arising from the farm and intervention to the problems are realized in a shorter time.
6. The natural landscape in the facility usage area should be given importance; especially endangered species of plants should not be harmed. Legislation, regulations, standards, and practices covering long years for such production in the country should be carried out and implemented in conjunction with both the production authorities and the population living in the region. In addition, activities that can eliminate environmental problems arising from fish farms should be concentrated on.

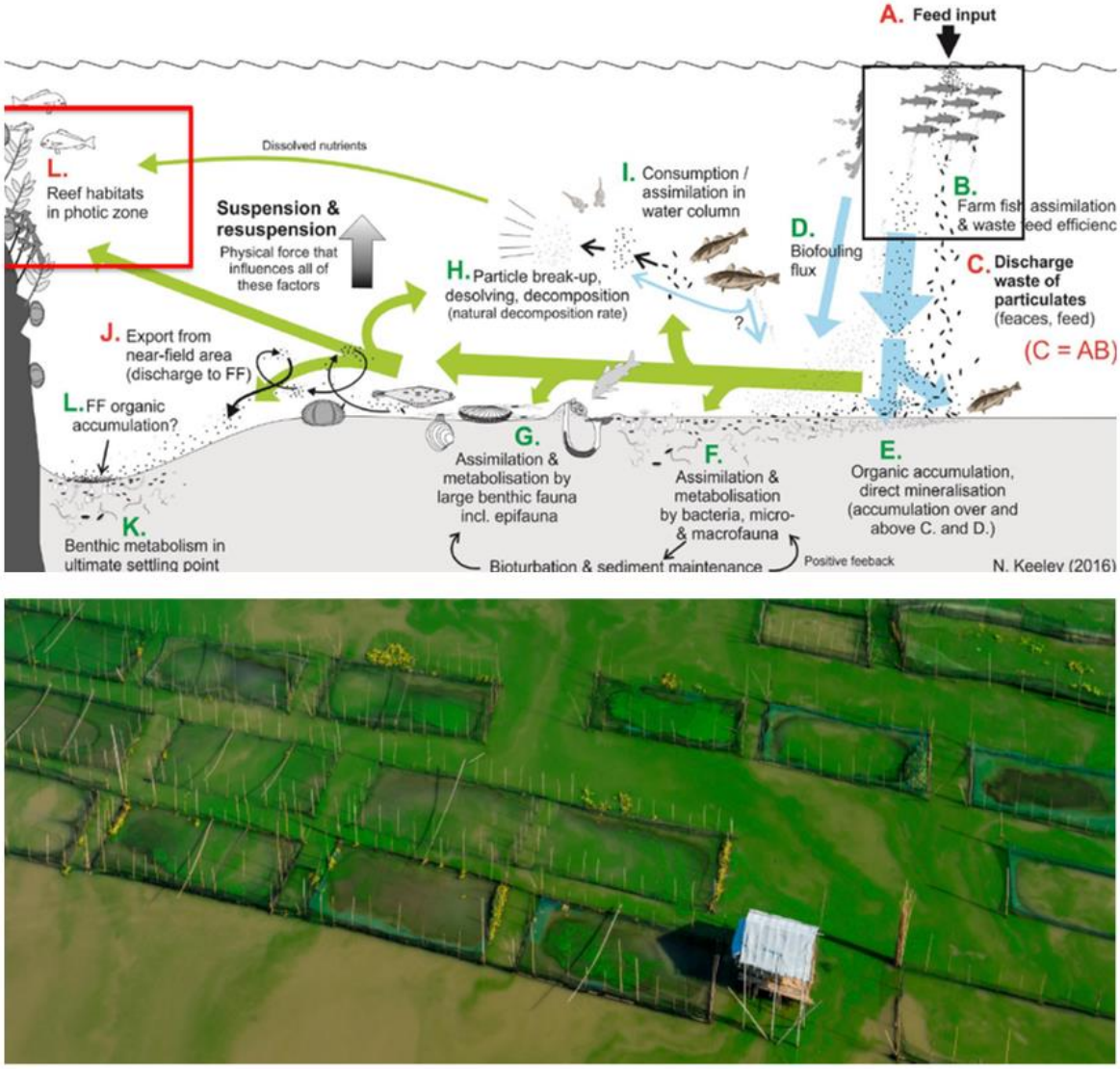

Fig. 5. Discharges and changes in the water environment of organic charges (Coldebella et al., 2018; Jakobsen *et al.*, 2017; Abu Bakar *et al.*, 2016; Buschmann *et al.*, 2009).

REFERENCES

Abu Bakar, N. H., Jusoh, A., Ahmad, M. F., Noor, M. J. M. M., Norzilah, A. (2016). " A Spatial nutrient distribution due to seabass aquaculture activities at Setiu, Terengganu, Malaysia." *Journal of Fisheries and Aquatic Science,* Vol. 11, pp. 332-348.

Agoba, E. E., Adu, F., Agyare, C., Boamah, V. E. (2017). "Antibiotic use and practices in selected fish farms in the Ashanti Region of Ghana." *Journal of Infectious Diseases and Treatment,* Vol. 3, pp. 1-6.

Aydın, H., Baltacı, M.A. (2017). "Türkiye'de alabalık üretiminin yaygınlaşmasında istanbul üniversitesi sapanca içsu ürünleri üretimi araştırma ve uygulama birimi'nin yeri." *Turkish Journal of Aquatic Sciences,* Vol. 32, No. 3, pp. 129-134.

Baba, E. (2017). "Su ürünleri yetiştiriciliğinde bitkisel immunostimulant kullanımı." *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* Vol. 7, No. 3, pp. 249-256.

Bengtsson-Palme, J., Larsson, D. G. J. (2015). "Antibiotic resistance genes in the environment: prioritizing risks." *Nature Reviews Microbiology,* Vol. 13, p. 396.

Buschmann, A. H., Cabello, F., Young, K., Carvajal, J., Varela, D. A., Henriquez, L. (2009). "Salmon aquaculture and coastal ecosystem health in Chile: Analysis of regulations, environmental impacts and bioremediation systems." *Ocean and Coastal Management,* Vol. 52, pp. 243-249.

Bureau, D. P., Gunther, S. J., Cho, C. Y. (2003). "Chemical composition and preliminary theoretical estimates of waste outputs of rainbow trout reared in commercial cage culture operations in Ontario." *North American Journal of Aquaculture,* Vol. 65, pp. 33-38.

Caruso, G. (2016). "Antibiotic resistance in fish farming environments: a global concern." *Journal of Fisheries Sciences,* Vol. 10, No. 4, pp. 9-13.

Cengizler, İ., Aytaç, N., Aldık, R. (2017). "Biocide use and its potential risks in aquaculture in Turkey." *Eastern Anatolian Journal of Science,* Vol. 3, No. 1, pp. 1-5.

Chen, C.Q., Zheng, L., Zhou, J.L., Zhao, H. (2017). "Persistence and risk of antibiotic residues and antibiotic resistance genes in major mariculture sites in Southeast China." *Science of the Total Environment,* Vol. 580, pp. 1175-1184.

Chen, H., Liu, S., Xu, X. R., Diao, Z. H., Sun, K. F., Hao, Q. W., Liu, S. S., Ying, G. G. (2018). "Tissue distribution, bioaccumulation characteristics and health risk ofantibiotics in cultured fish from a typical aquaculture area." *Journal of Hazardous Materials,* Vol. 343, pp. 140-148.

Coldebella, A., Gentelini, A. L., Piana, P. A., Codebella, P. F., Boscolo, W. R., Feiden, A. (2018). "Effluents from fish farming ponds: a view from the perspective of its main components." *Sustainability,* Vol. 10, pp. 1-16.

Di Cesare, A., Luna, G.M., Vignaroli, C., Pasquaroli, S., Tota, S., Paroncini, P., Biavasco, F. (2013). "Aquaculture can promote the presence and spread of antibiotic-resistant Enterococci in marine sediments." *PLoS One,* Vol. 8, pp. e62838.

Dolan, E., Murphy, N., O'Hehir, M. (2013). "Factors influencing optimal micro-screen drum filter selection for recirculating aquaculture systems." *Aquacultural Engineering,* Vol. 56, pp. 42-50.

Elevancini, J. S. (2017). How do third-party certifications control the use of antibiotics in global salmon aquaculture?, PhD Thesis, Dalhousie University, Halifax, Nova Scotia.

Guo, J. H., Li, J., Chen, H., Bond, P. L., Yuan, Z. G. (2017). "Metagenomic analysis reveals wastewater treatment plants as hotspots of antibiotic resistance genes and mobile genetic elements." *Water Research,* Vol. 123, pp. 468-478.

Harnisz, M., Korzeniewska, E., Gołaś, I. (2015). "The impact of a freshwater fish farm on the community of tetracycline-resistant bacteria and the structure of tetracycline resistance genes in river water." *Chemosphere,* Vol. 128, pp. 134-141.

Holmer, M. (2010). "Environmental issues of fish farming in offshore waters: perspectives, concerns and research needs." *Aquaculture Environment Interactions,* Vol. 1, pp. 57-70.

Jakobsen, H. R., Skarra, H., Arvesen, M. P. (2017). *Nordic Conference 2017-Aquaculture,* Technical Report, Norway.

Karaman, S. (2006). "Hayvansal üretimden kaynaklanan çevre sorunları ve çözüm olanakları." *KSÜ Fen ve Mühendislik Dergisi,* Vol. 9, No. 2, pp. 133-139.

Kayhan, M. H., Olmez, M. (2014). "Aquaculture and organic aquaculture in Turkey." *Journal of Aquaculture Research & Development,* Vol. 5, No. 5, pp. 1-5.

Kim, H. Y., Lee, I. S., Oh, J. E. (2017). "Human and veterinary pharmaceuticals in the marine environment including fish farms in Korea." *Science of the Total Environment,* Vol. 579, pp. 940-949.

Kim, Y. B., Jeon, J. H., Choi, S., Shin, J., Lee, Y., Kim, Y. M. (2018). "Use of a filtering process to remove solid waste and antibiotic resistance genes from effluent of a flow-through fish farm." *Science of the Total Environment,* Vol. 615, pp. 289-296.

Koca, S. B., Terzioğlu, S., Didinen, B. I., Yiğit, N. Ö. (2011). "Sürdürülebilir su ürünleri yetiştiriciliğinde çevre dostu üretim." *Ankara Üniversitesi Çevrebilimleri Dergisi,* Vol. 3, No. 1, pp. 107-113.

Kumar, V., Roy, S. (2017). "Aquaculture drugs: sources, active ingredients, pharmaceutic preparations and

methods of administration." *Journal of Aquaculture Research and Development,* Vol. 8, No. 9, pp. 1-13.

Li, S., Shi, W., Liu, W., Li, H., Zhang, W., Hu, J., Ke, Y., Sun, W., Ni, J. (2018). "A duodecennial national synthesis of antibiotics in China's major rivers and seas (2005-2016)." *Science of the Total Environment,* Vol. 615, pp. 906-917.

Luo, Y., Mao, D., Rysz, M., Zhou, Q., Zhang, H., Xu, L., Alvarez P. J. J. (2010). "Trends in antibiotic resistance genes occurrence in the Haihe River, China." Environmental Science and Technology, Vol. 44, pp. 7220-7225.

Mancuso, M. (2015). "Effects of fish farming on marine environment." *Journal of Fisheries Sciences,* Vol. 9, No. 3, pp. 89-90.

Martinez, J. L., Coque, T. M., Baquero, F. (2015). "What is a resistance gene? Ranking risk in resistomes." *Nature Reviews Microbiology,* Vol. 13, pp. 116-123.

Meador, J. P., Yeh, A., Young, G., Gallagher, E. P. (2016). "Contaminants of emerging concern in a large temperate estuary." *Environmental Pollution,* Vol. 213, pp. 254-267.

Miranda, C. D., Godoy, F. A., Lee, M. R. (2018). "Current status of the use of antibiotics and the antimicrobial resistance in the chilean salmon farms." *Frontiers in Microbiology,* Vol. 9, 1-14.

Mirzoyan, N., Tal, Y., Gross, A. (2010). "Anaerobic digestion of sludge from intensive recirculating aquaculture systems: review." *Aquaculture,* Vol. 306, pp. 1-6.

Mishra, S. S., Das, R., Choudhary, P., Debbarma, J., Sahoo, S. N., Swain, P., Rathore, R., Giri, B. S. (2017). "Prevalence of fish and shrimp diseases and use of various drugs and chemicals in ındian aquaculture for disease management." *Journal of Fisheries and Aquaculture Development,* Vol. 2017, No. 6, pp. 1-16.

Neary, E. T., Develi, N., Yüksel, S. A. (2008). "Su ürünleri yetistiriciliginde kullanılan aşılar." *GOÜ Ziraat Fakültesi Dergisi,* Vol. 25, No. 2, pp. 29-35.

Opiyo, M. A., Marijani, E., Muendo, P., Odede, R., Leschen, W., Charo-Karisa, H. (2018). "A review of aquaculture production and health management practices of farmed fish in Kenya." *International Journal of Veterinary Science and Medicine,* (article in press).

Orçun, E., Sunlu, U. (2007). "Sığacık (Seferihisar-İzmir) Bölgesi Ağ Kafeslerde Yapılan Balık Yetiştiriciliğinin Sucul Ortama Olan Etkilerinin Araştırılması." *E.Ü. Su Ürünleri Dergisi*, Vol. 24, No. 1-2, pp. 1-9.

Özdal, B., Pulatsü, S. (2012). **"**Ağ kafeslerde sürdürülebilir balık yetiştiriciliği için bir bilgisayar yazılımının kullanımı." *Ankara Universitesi Cevrebilimleri Dergisi,* Vol. 4, No. 1, pp. 15-26.

Rahman, Md. Z., Khatun, A., Kholil, Md. I., Hossain, Md. M. M. (2017). "Aqua drugs and chemicals used in fish farms of Comilla regions." *Journal of Entomology and Zoology Studies,* Vol. 5, No. 6, pp. 2462-2473.

Rein, A., Wu, Y., Yemelyanova, M. (2015). *Phosphorus Project: Sea Breeze, IV.* Project Report, Denmark.

Schumann, M., Unger, J., Brinker, A. (2017). "Floating faeces: effects on solid removal and particle size distribution in RAS." *Aquacultural Engineering,* Vol. 78, pp. 75-84.

Scott, W. C. C., Du, B., Haddad, S. P., Breed, C. S., Saari, G. N., Kelly, M., Broach, L., Chambliss, C. K., Brooks, B. W. (2015). "Predicted and observed therapeutic dose exceedences of ionizable pharmaceuticals in fish plasma from urban coastal systems." *Environmental Toxicology and Chemistry,* Vol. 35, No. 4, pp. 983-995.

Topçu, A., Pulatsü, S., Kaya, D. (2017). *"*Almus baraj gölü (Tokat)'nde kafeslerde gökkuşağı alabalığı yetiştiriciliğinin sedimentten fosfor salınımına etkisi." *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* Vol. 7, No. 2, pp. 295-302.

Türk, E. (2015). Muğla bölgesindeki balık çiftlikleri çevresinden avlanan balıklarda tetrsiklin aranması, Doktora Tezi, Selçuk Üniversitesi, Konya, Türkiye.

Tran, N. H., Chen, H. J., Reinhard, M., Mao, F., Gin, K. Y. H. (2016). "Occurrence and removal of multiple classes of antibiotics and antimicrobial agents in biological wastewater treatment processes." *Water Research,* Vol. 104, pp. 461-472.

Türk, E., Oğuz, H. (2013). "Kültür balıkçılığında ilaç kullanımı ve halk sağlığı açısından önemi." *Bornova Veteriner Bilimleri Dergisi,* Vol. 35, No. 49, pp. 35-43.

Uma, A., Rebecca, G. (2018). "Antibiotic resistance in bacterial isolates from commercial probiotics used in aquaculture." *International Journal of Current Microbiology and Applied Sciences,* Vol. 7, No. 1, pp. 1737-1743.

URL-1, Ağ Kafeslerde Balık Yetiştiriciliğinin Su Kalitesine Etkisi, https://acikders.ankara.edu.tr [Accessed 26 July 2018].

Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P., Teillant, A., Laxminarayan, R. (2015). "Global trends in antimicrobial use in food animals." *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 112, No. 8, pp. 5649-5654.

Xiong,W., Sun, Y., Zhang, T., Ding, X., Li, Y.,Wang, M., Zeng, Z. (2015). "Antibiotics, antibiotic resistance genes, and bacterial community composition in fresh water aquaculture environment in China." *Microbial Ecology,* Vol. 70, pp. 425-432.

Yang, Y., Liu, W., Xu, C., Wei, B., Wang, J. (2017a). "Antibiotic resistance genes in lakes from middle and

lower reaches of the Yangtze River, China: effect of land use and sediment characteristics." *Chemosphere,* Vol. 178, pp. 19-25.

Yang, Y., Song, W., Lin, H., Wang, W., Du, L., Xing, W. (2018). "Antibiotics and antibiotic resistance genes in global lakes: A review and meta-analysis." *Environment International,* Vol. 116, pp. 60-73.

Yang, Y., Xu, C., Cao, X., Lin, H., Wang, J. (2017b). "Antibiotic resistance genes in surface water of eutrophic urban lakes are related to heavy metals, antibiotics, lake morphology and anthropic impact." *Ecotoxicology,* Vol. 26, pp. 831-840.

Yavuzcan, H., Pulatsü, S., Demir, N., Kırkağaç, M., Bekcan, S., Topçu, A., Doğankaya, L., Basçınar, N. (2010). "Türkiye'de Sürdürülebilir Su Ürünleri Yetistiriciliği." *TMMOB Ziraat Mühendisliği VII. Teknik Kongresi*, Ankara, Türkiye, pp.767-789.

Yayan, D. T. (2015). Durgun sularda balık yetiştiriciliğinin besin elementleri açısından etkilerinin azaltılması, Uzmanlık Tezi, Türkiye Cumhuriyeti Orman ve Su İşleri Bakanlığı, Ankara, Türkiye.

Yeo, S. F., Binkowski, F. P., Morris, J. E. (2004). "Aquaculture effluents and waste by-products characteristics, potential recovery, and beneficial reuse." *NCRAC Technical Bulletins,* Vol. 6, pp. 1-41.

Yıldırım, Ö., Korkut, A. Y. (2004). "Su ürünleri yemlerinin çevreye etkisi." *Ege Üniversitesi Su Ürünleri Dergisi,* Vol. 21, No 1-2, pp. 167-172.

Zhao, Z., Wang, J., Han, Y., Chen, J., Liu, G., Lu, H., Yan, B., Chen, S. (2017). "Nutrients, heavy metals and microbial communities co-driven distribution of antibiotic resistance genes in adjacent environment of mariculture." *Environmental Pollution,* Vol. 220, pp. 909-918.

Zhong, Y., Chen, Z. F., Dai, X., Liu, S. S., Zheng, G., Zhu, X., Liu, S., Yin, Y., Liu, G., Cai, Z. (2018). "Investigation of the interaction between the fate of antibiotics in aquafarms and their level in the environment." *Journal of Environmental Management,* Vol. 207, pp. 219-229.