Food safety aspects of common carp produced in wastewater-fed fish ponds

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Abstract. There is an increasing trend in the use of wastewater in fish production because wastewater-based aquaculture is a sustainable, biological way to treat and recycle wastewater. Different fish species including common carp have been reared in wastewater-fed ponds. However, untreated wastewater contains many kinds of contaminants that have adverse effects on human health and the environment. Thus, the health risks arising from fish produced in wastewater-filled fish ponds seem undeniable. On the other hand, the appropriate use of wastewater in aquaculture has important environmental and economic significance, including recycling nutrients and reuse of water. The main objective of the present review is verification of rearing fish in purified wastewater-fed fishponds through revision of available data related to fish meat safety. Wastewater could be an excellent source of nutrients for fish, but proper purification of this waste stream is necessary. Fish also have a role as bioindicators of the effectiveness of wastewater purification. Continuous monitoring of the presence and concentration of different contaminants in common carp and other fish species reared in purified wastewater is very important.

1. Introduction

The use of wastewater in aquaculture is a common practice in some parts of the world, mainly in Asian countries, but there are increasing possibilities for such practice in Europe and in Serbia. Moreover, different integrated food production systems involving aquaculture are used in Asian countries [1]. Such systems contribute to optimal use of land, water and solar energy in order to reach high yields with low financial investment. Wastewater provides a good source of nutrients for fish and consequently reduces the need for fertilisation of fish ponds. Besides, these advantages, various integrated livestock-fish culture systems utilise animal excreta as fish pond fertilisers. Such practice contributes to growth of plankton and other organisms in the ponds and consequently to fish growth. Thus, wastewater-based aquaculture is a sustainable, biological way to treat and recycle wastewater. The main objective of this review is verification of rearing fish in purified wastewater fed fishponds through revision of available data on fish meat safety.

Different fish species have been reared in wastewater-fed ponds. Filter feeders are recommended due to their ability to exploit plankton, but omnivorous species and bottom feeders such as common carp are also considered suitable for this purpose [2]. Common carp is one of the most commonly reared fish in different parts of the world [3]. Fast growth rate, beneficial feed conversion ratio and relative resistance to poor environmental conditions and diseases are the main reasons that common carp is a highly esteemed fish species, and that it is the most widespread farmed fish species in Serbia. Moreover, these characteristics contribute to the fact that common carp could be successfully reared in wastewater-fed
ponds or various types of integrated culture systems. The main reason for increasing demand for fish including common carp is that fish is considered as a healthy food [4]. Moreover, fish is an excellent source of fatty acids in healthy nutrition [5]. On the other hand, consumers are increasingly directing their attention towards safety requirements associated with fish consumption due to the presence of different environmental contaminants, especially if fish are reared in wastewater-fed ponds or integrated production systems. It is important to increase public awareness related to the risks associated with consumption of fish containing these contaminants.

2. Use of wastewater in aquaculture
There is increasing use of wastewater in fish production, particularly in developing countries. The alternative aquaculture production systems such as utilising wastewater for fish rearing or different integrated fish production systems are important from various viewpoints: environmental protection, sustainability, food safety, food quality, economic significance and scientific importance. However, there are still many questions regarding the use of wastewater in aquaculture. This topic is also very important from the human health protection point of view, since many industrial facilities discharge wastewater directly into waterways, which can compromise environmental quality. On the other hand, purified wastewater could be an excellent source of nutrients for fish. Wastewater used for this purpose must be purified as a necessary first step. Fish also have a role as bioindicators of the effectiveness of wastewater purification.

3. Public health risks related to the use of wastewater in aquaculture
Rearing fish in wastewater could produce significant risks for public health [6]. Besides, fish can act as bioindicators of environmental contamination. Thus, the safety of fish reared in wastewater-filled ponds is a public health concern. The potential public health risks associated with this practice include bacterial and parasitic infections like diarrhoea and skin infections. Untreated wastewater can contain many kinds of contaminants with adverse effects on human health and the environment such as pathogenic microorganisms, heavy metals, pesticides, antibiotics and hormones [7]. On the other hand, the appropriate use of wastewater in aquaculture has important environmental and economic significance, including recycling nutrients and reuse of water.

Dang and Dalsgaard [8] showed low levels of faecal contamination in muscle tissues of silver carp, grass carp and rohu reared in household-based integrated systems where pig farming was integrated with fish farming and horticulture. However, high levels of *Escherichia coli* were observed in the gut of the studied fish. The authors concluded the prevention of faecal cross-contamination during degutting and preparing fish for consumption at the market or in the home are the main critical points to control the food safety of fish flesh produced in integrated systems. Edwards [9] noted high levels of *E. coli* in the fish digestive tract contents but low levels in the muscle tissue of fish from fish ponds fed with urban wastewater in different Asian countries. Furthermore, fish reared in fish ponds fertilised with urban wastewater contained very low levels of thermotolerant coliforms in muscle tissue, but their skin and digestive tract contents were highly contaminated [10]. Development and transmission of antibiotic resistant bacteria and transmission of resistance genes to fish and humans are serious potential food safety risks related to integrated livestock and wastewater-based fish farming systems [11]. Antibiotic resistance can increase among microorganisms in aquaculture environments due to the selective pressure of the antibiotics used as growth promoters or for medical purposes [12]. Additionally, antibiotic resistant microorganisms could be introduced to wastewater-fed fish farm waters via animal manure.

Other food safety hazards associated with usage of wastewater in aquaculture production include fishborne zoonotic parasites that can be transmitted to humans through consumption of raw or improperly prepared fish [13]. Hop et al. [14] reported that fish from peri-urban wastewater-fed aquaculture systems are at risk of infection with trematodes, but the prevalence was low compared to previous findings of trematodes in non-wastewater fish elsewhere in Vietnam. Pigs can be a reservoir host for trematodes, and eggs could be introduced into fish ponds via infected pigs’ waste [15]. The use of exclusively commercial feed in pig nutrition and proper heat treatment of fish before consumption are the main methods for prevention of transmission of trematodes. Furthermore, significant safety concerns in fish are toxic metals and metalloids that accumulate in fish after dietary exposure or
absorption through gills [16]. Unacceptable levels of arsenic, cadmium, mercury and lead in fish are serious food safety risks. The data regarding metal levels in fish reared in wastewater-fed ponds are very scarce. According to results obtained by Marcussen et al. [17], consumption of common carp, silver carp and tilapia flesh produced in wastewater-fed ponds in Vietnam did not present a food safety problem in terms of arsenic, cadmium and lead. On the other hand, Mansour and Sidky [18] reported that levels of cadmium and lead in fish caught in a lake receiving water from agriculture and fish production were above the threshold values [19]. Potentially toxic elements, mainly heavy metals, in fish and water spinach from Hanoi and Cheung Ek Lake in Phnom Penh constituted low food safety risks for consumers, and consumption of muscle tissue from fish produced in wastewater-fed systems resulted in an estimated intake of these elements amounting to less than 9% of the tolerable daily intake [20].

Pesticides are present in aquatic sediments and can be transferred into the aquatic environment and finally enter into the food chain [21]. Because their solubility in lipids is high, pesticides tend to accumulate in fatty tissues of fish [22]. According to WHO [23], some of the older, low cost pesticides, including dichlorodiphenyltrichloroethane (DDT) and lindane, can remain in soil and water for years. These pesticides are officially prohibited from use in agricultural practice in developed countries, but they are still in use in many developing countries, so they could be present in wastewater and consequently in fish from wastewater-fed fishponds. There is evidence of high concentrations of DDT and its metabolites in the environment in different parts of the world [24]. Having in mind all the above-mentioned risks associated with the use of wastewater, the purification of wastewater before use in aquaculture is necessary. Fish could have a role as bioindicators of the effectiveness of wastewater purification treatment. Khalil and Hussein [25] reported that the primary and secondary treated waste effluents were successfully used to grow Nile tilapia.

4. Possibility of wastewater use in aquaculture in Serbia
In Serbia, vast unused land areas near slaughterhouses or various food industry facilities are not cultivated or suitable for other agricultural activities but could be used for aquaculture. Currently, fish production in Serbia mostly consists of the traditional rearing system, which is a semi-intensive culture system, and the diet of fish is based on a combination of natural food and supplementary feed (cereals, such as wheat, maize, barley or extruded feed mixtures). Similar fish-farming techniques are found in many countries worldwide. Rural areas would be ideal hotspots for developing integrated fish production since the land is far away from human settlements, purified wastewater could be used for filling ponds, thus significantly reducing the release of harmful agents into waterways and the environment, and applying appropriate piscicultural practices could lead to favourable natural food composition. Wastewaters from slaughterhouses in developing countries are discharged into rivers, lakes and seas without being adequately treated. Such wastewater contains suitable amounts of organic matter that would be an ideal material for fish nutrition and for development of different microorganisms.

5. Consumer attitude towards fish produced in wastewater
The reuse of wastewater in aquaculture is accepted and practiced worldwide. However, it is very important that the whole process is applied with precautionary measures and strictly controlled. The presence of microbial pathogens, parasites and toxic chemicals in fish, water and sediment must be monitored. Also, the acceptance of such fish by consumers is a very important issue. According to Mancy et al. [26], consumers in Egypt did not accept fish produced in treated sewage water despite the fact that the fish produced were suitable for human consumption. Consumer behaviour and cultural habits could be the leading reasons against the use of wastewater in fish farming, besides public health and food safety concerns. Consumer acceptance of wastewater-based fish farming and the requirements of public health protection demand proper treatment of wastewater before its usage in aquaculture production.

6. Preventive measures against harmful agents in fish
The best preventive measures against microbial contaminants in fish are avoiding consumption of raw and uncooked fish. Health education is an important factor in minimising risks associated with
consumption of fish reared in wastewater-fed fishponds. Aquaculturalists must ensure that fish are subjected to visual inspection for parasites before being placed on the market [27]. There are also various obligatory microbiological and chemical analyses before fish can be placed on the market. Recommended methods for eliminating or minimising microbial contamination of fish are freezing, heating, combinations of salt and storage time and hot smoking among others [28]. The health risk is significantly reduced by adequate heat treatment of fish before consumption.

Most pathogens that enter wastewater-fed fish ponds migrate into and populate the pond sediment and so are health risks for anybody entering the pond during fish harvesting. Fish harvesters must adopt adequate personal hygiene measures for their own health protection. Guidelines for the safe use of wastewater and excreta in aquaculture [29] focus on microbial safety, but there are also some recommendations related to toxic elements. Depuration, i.e. holding fish in clean water for several weeks before consumption, is mentioned as a method for decontamination of fish reared in wastewater-fed ponds, but there is a need for more scientific evidence of this. The management of wastewater is still a great problem in the majority of countries worldwide and inadequate management could lead to serious health problems. The safe use of wastewater for fish rearing should be encouraged. For that purpose, proper treatment of wastewater must be applied before its use.

7. Conclusions
People employed at fish pond facilities, people living near these facilities and consumers of the fish produced are specific populations at risk of exposure to various contaminants related to integrated fish production systems and wastewater-fed fish ponds. Additional studies are required in order to understand the health risks associated with these types of fish production and to develop suitable measures for reduction or prevention of human health risks. Continuous monitoring of the presence and concentration of different contaminants in common carp and other fish species reared in purified wastewater is very important, having in mind that fish is an important food source but also is also an important indicator of environmental contamination. Research should provide important data for the exposure assessment part of risk assessments for contaminants from fish reared in purified wastewater. Furthermore, research would be helpful to fish processors for developing quality assurance programs for fish raised in integrated production systems. Undoubtedly, adequate treatment of wastewater is required before its use in aquaculture.

Acknowledgments
This review is a result of research within project TR 31011, financed by the Ministry of Science and Technological Development, Republic of Serbia.

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