EFFECTS OF AGRICULTURE ON SURFACE AND SUBSURFACE WATER RESOURCES – A REVIEW

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Abstract

Surface and subsurface water resources are vital elements in the functioning of environmental processes and human society. In favour of sustainability, it is extremely important to maintain their good quality, quantity and exemption from harmful substances. In this literature review the agricultural activities - causing greater negative impact on surface and subsurface water resources - will be presented. The current regulatory status of surface- and groundwater in Hungary will be explained, just like agricultural activities, endangering water resources, and harmful substances derived therefrom, which move the state of the waters to a negative direction. Furthermore, currently available and long-term perspectives will be presented to eliminate the harmful effects of agricultural activities. The main aim of the review is to draw

attention to the way and extent, how industrial agriculture damages and changes the quality, quantity and wildlife of water bodies.

Keywords: water resources, eutrophication, fertilizers, insecticides, erosion, irrigation

Összefoglalás

A felszíni és felszín alatti vízbázisok a környezeti folyamatok és az emberi társadalom működésében egyaránt létfontosságú elemek. Ezek mennyiségének, minőségének és káros anyagoktól való mentességének megőrzése, a fenntarthatóság érdekében kulcsfontosságú. Ebben a szakirodalmi áttekintésben a nagyobb negatív környezeti befolyást okozó mezőgazdasági tevékenységek, felszíni és felszín alatti vizekre gyakorolt hatása kerül kifejtésre. Áttekintést kaphatunk a Magyarországi felszíni és felszín alatti vizek jellemzőinek hatályos szabályzásáról, a mezőgazdaság vízbázisokat veszélyeztető tevékenységeiről, az ezekből kikerülő és károsító anyagokról, valamint ezek hatásairól, melyek negatív irányba mozdítják el a vizek állapotát. Továbbá, szó lesz még arról, hogy milyen jelenlegi és jövőbeni megoldások vannak, és lehetnek majd arra, hogy a mezőgazdaság vizeket károsító hatását mérsékeljük. Az áttekintés fő célja felhívni a figyelmet arra, hogy az iparszerű mezőgazdaság milyen módon és milyen mértékben károsítja és változtatja meg a vízbázisok minőségét, mennyiségét és élővilágát.

Kulcsszavak: vízkészletek, eutrofizáció, műtrágya, rovarölőszer, erózió, öntözés

Introduction

Until the 1950s, agricultural activities were carried out on smaller family farms that used organic fertilizers. After that, there was a worldwide shift in agricultural production, which was relocated to larger, monocultural, intensively operated farm units (Novotny, 1999). Along with the population explosion, the demand for agricultural production has also increased. The

population of the world is now around 7.8 billion (INTERNET 1), and because of that, only industrial agriculture is appropriate to feed so many people.

The intensification of agriculture and population growth went hand in hand. The quality and quantity of agricultural products are very important, but this sector has an inevitable impact on water quality, which has direct and indirect effects on fertility, so it can be said, that the purity of water and fertility are closely related. Agriculture pollutes water resources as a result of the usage of agrochemicals, organic substances, saltwater drainage and pollution with toxic materials threatening human health and water ecosystems (Stoyanova et al., 2019). The agricultural sector is mainly responsible for nitrate, phosphorus, pesticide, salt, pathogen and soil sediment pollution of surface and subsurface waters, especially from crop and livestock activities (Parris, 2011). From these, eutrophication (the accumulation of the two key nutrients – nitrogen (N) and phosphorus (P)) and the contamination of subsurface and drinking water sources are the main problems in most of the countries. Unsustainable land use can also lead to water pollution.

The entire land surface functions as a catchment area for rivers, and almost every event on the catchment area have a large effect on freshwaters (Moss, 2008). Freshwater and marine ecosystems have all been degraded because of production, but freshwaters are the most vulnerable. The surface and subsurface water bodies are widely exploited (Withers et. al., 2014).

Water classification in Hungary

In Hungary, the MSZ 12749 standard - effective from 1. January 1994 - classifies surface waters into five quality classes, based on specific water characteristics. Table 1 shows the main

parameters that can be released into water, as a result of agricultural activities, according to the standard.

Table 1 The main surface water quality parameters that change as a result of agricultural activities (MSZ 12749 standard)

Water quality characteristics	**Unit of measure**	**Excellent (I.)**	**Good (II.)**	**Bearable (III.)**	**Contaminated (IV.)**	**Heavily contaminated (V.)**
Dissolved oxygen	mg/l	7	6	4	3	<3
Oxygen saturation	%	80-100	70-80	50-70	20-50	<20
Biological oxygen demand	mg/l	4	6	10	15	>15
Chemical oxygen demand	mg/l	5	8	15	20	>20
NH_4^+	mg/l	0.26	0.64	1.29	2.57	>2.57
NO_2^-	mg/l	0.033	0.1	0.329	0.986	>0.986
NO_3^-	mg/l	4.43	22.14	44.28	110.7	>110.7
total phosphorus	µg/l	100	200	400	1000	>1000
Chlorophyll-A	µg/l	10	25	75	250	>250
Coliform count in 1 ml	-	1	10	100	1000	>1000
Cyanide	µg/l	10	25	50	100	>100
Zinc	µg/l	50	75	100	300	>300
Mercury	µg/l	0.1	0.2	0.5	1	>1
Cadmium	µg/l	0.5	1	2	5	>5
Lead	µg/l	5	20	50	100	>100
Copper	µg/l	5	10	50	100	>100
Phenols	µg/l	2	5	10	20	>20
Petroleum and products thereof	µg/l	20	50	100	250	>250
Polychlorinated biphenyls	µg/l	0.01	0.05	0.2	2	>2
pH	-	6.5-8	6.5-8.5	6-6.5	5.5-6	<5.5
Iron	mg/l	0.1	0.2	0.5	1	>1
Manganese	mg/l	0.05	0.1	0.1	0.5	>0.5

In Hungary, the quality of 109 watercourses and 4 lakes is currently regularly monitored, at a total of 241 locations. Environmental inspectorates take thousands of water samples every year.

Agricultural pollution of water resources

Fertilization

Chemical substances (artificial fertilizers) are used extensively in industrial agriculture in order to improve crop yield (Divja et al., 2012). Nutrients and other even harmful substances released from the fertilizers can easily enter surface- and groundwater through precipitation and runoff. The leading problem of fertilizers is that, if their main nutrients like nitrogen and phosphorus are not utilized and leached, they pollute water. These two nutrients are predominant pollution sources, causing harmful algal blooms and eutrophication (Wu, 2017). Eutrophication is a feature of surface waters. In 1995, Nixon formulated the definition of eutrophication as ”an increase in the rate of supply of organic matter to an ecosystem”. Thanks to the widespread use of fertilizers, agricultural nutrient pollution became an essential problem across the developed agricultural countries (Parris, 2011). Eutrophication occurs naturally over decades or centuries as lakes are filled with sediments, under the influence of natural processes (Carpenter, 1981). These processes are accelerated by human activities. Agricultural scientist and pond managers often eutrophy experimental water bodies and fish ponds by adding fertilizers to enhance primary productivity and increase the density and biomass, to grow economically important fish faster (Boyd and Tucker, 1998). Extra nutrients that can be consumed under artificial conditions cannot be utilized by natural water bodies, so it will cause undesired algal blooms. Algal blooms limit light penetration with which they lower the success of predators that need light to catch prey, and causing die-offs of plants in littoral zones (Lehtiniemi et al., 2005). Another impact of eutrophication causing dissolved nutrients like nitrogen and phosphorus, is when a water body becomes enriched in them, the increased growth of aquatic plant life can lead to the depletion of dissolved oxygen (Vallero, 2006). Beside the oxygen consumption of algae, metabolic breakdown of organic matter can also cause depletion of dissolved oxygen

concentration, leading to hypoxia (very low oxygen level) or anoxia (no oxygen), which is fatal to the natural flora and fauna (Sharp, 2001).

Artificial yield enhancers has also a relevant negative effect on subsurface and drinking waters as nitrate transforms into nitrite. It is a dangerous contaminant, because it can cause methaemoglobinaemia (blue baby syndrome). The maximum allowable concentration of nitrate and nitrite in order to prevent human diseases has been set by the World Health Organization. Due to the 201/2001. (X.25.) Government decree, in Hungary the maximum concentration of nitrate could not be above 50 mg/l and nitrite could not be above 0.5 mg/l. To prevent the contamination of subsurface waters and damages to human health, the application of fertilizers, containing nitrogen compounds is highly restricted. In their study Parvizishad et. al. (2006) examined the adverse effects and benefits of nitrite and nitrate in drinking water to reconsider the specified limits. They came to the conclusion that the risk is not clear, because as these substances can cause methaemoglobinaemia, cancer, enlargement of the thyroid gland, or diabetes mellitus in high doses, they are also advantageous in the protection of the vascular system, blood pressure regulation and maintaining the homeostasis in small quantities.

Fertilizers often contain heavy metals and microelements which can also be harmful to water ecosystems and human health. These heavy metals may accumulate in soil with repeatable fertilizer applications and they can easily reach surface and groundwater through the water cycle. Possibly occurring and most important heavy metals in fertilizers are cadmium (Cd), arsenic (As), chromium (Cd), lead (Pb), mercury (Hg), nickel (Ni) and vanadium (V) (Mortvedt, 1995).

Chemical plant protection

Nowadays the use of pesticides, herbicides, insecticides, fungicides and other artificial plant protectants became common all around the world, not only on agricultural farms, but in backyard gardens as well. These chemicals have allowed farmers and gardeners to exercise greater control over the plants they want to grow, by warding off pests. But this high degree of chemicalization have not come without environmental costs like pollution of surface and subsurface waters. In the history of mankind, a plenty of substances were used in rudimentary- and developed agriculture. In the 15th century, toxic chemicals containing arsenic, lead and mercury were used. In the 17th century, nicotine-sulphate was used as an insecticide (Miller, 2002). In the 1960's triazine, carboxyl-acids such as glyphosate and other nitrogen-containing herbicides and pesticides became common (Ritter, 2009). Artificial chemicals threat waters and their biodiversity seriously. A good example of contamination of plant protection is DDT (dichloro-diphenyl-trichloroethane) which was a highly effective insecticide and was used massively worldwide until 1972, when it was banned internationally under the Stockholm Convention on Persistent Organic Pollutants, due to its persistence and accumulation mainly in water food chains (Yang et al., 2008). The major problem of DDT and similar plant protectans is their capacity to accumulate in the food chain and thus threatening both human health and the environment (Ochoa-Rivero et al., 2017). This substance has accumulated in higher order organizations with biomagnification, and in the 1960s it was discovered, that it prevented a number of fish-eating birds from reproduction (Anamika et al., 2018). Unfortunately, DDT is still used in some developing countries, to prevent malaria and other tropical diseases (Lobe, 2006). Nowadays we have thousands of new ingredients for chemization, but we know little about their long-term environmental and health effects and persistence.

Irrigation

As a consequence of climate change, irrigation of agricultural and horticultural crops is becoming increasingly inevitable. As a result of climate change, less and less rain is expected, with more unpredictable frequency. Irrigated agriculture has many advantages, such as increased production and reliable harvests (Duncan et al., 2008). On the other side of the coin, this intervention has also negative effects on the quality and quantity of water resources. For example, aside from the positive impact of irrigation, in the downstream part of the river basin, it can cause salinity to build up with the increasing level of the groundwater (Kume et al., 2007). Salinity means the accumulation of salt in water to levels that impact on human and environmental assets. Irrigation salinity is a common unfavourable situation in irrigated landscapes. Primary salinity means the natural occurrence of salt in water (for example: salt lakes, salt marshes). Secondary salinity is the problem, which is a consequence of human activity, such as agricultural irrigation.

Many irrigation water sources have high content of salt (mostly magnesium, calcium and bicarbonates), so the reaction of these waters is alkaline (pH 7.2-8.5) (Mengel, 1994). Acidifying irrigation water is an available, but valuable technique for lowering the pH of irrigation water, but it has a number of benefits, especially for the receiving water bodies. Untreated and partially treated wastewater is also widely used for irrigation in agriculture. While the nutrients of the wastewater are considered as beneficial in agriculture, their other contaminants like heavy metals and bacteria means environmental (and also health) risks in water resources (Srinivasan et al., 2009). In their study Srinivasan et al. (2009) examined the impact of irrigation water quality on human health in India. They found that the morbidity rates were significantly higher in wastewater irrigated villages, than in the control villages, and its reason may be the quality change of drinking water resources.

Irrigation has also a mobilizing effect on nutrients, heavy metals and other elements and substances which can easily lead to the eutrophication or contamination of water sources. The most important task is to prevent the deterioration of water sources with proper water management and agrotechnology. To preserve the good quality of natural resources, irrigation is also strictly regulated. In Hungary, 2019 CXIII. Law on irrigation management is the newest and most up-to-date regulator on the subject of irrigation.

Animal husbandry

Just like other polluting agricultural sectors (fertilization or chemicalization) the livestock sector is also growing and intensifying unstoppably. One of the most dangerous pollution sources is livestock farming, whose production waste, including manure and slurry has serious implications for water quality (FAO, 2006). As a consequence of development, the quantity of produced waste has reached huge levels, because of the increasing number of farm animals housed per unit area (Polat et al., 2018).

The mixing of livestock wastes with surface waters lowers water quality and may cause the death of sole living organisms in water, by poisoning (Mielke, 1992). Livestock waste pollutes water, because it contains a high amount of nitrate, phosphorus, pathogenic microorganisms and high biological oxygen demanded organic materials (Polat et al., 2018). From these, the two main pollutants are nitrogen and phosphorus. The high concentration of nitrogen, in drinking water, in nitrate form cause methaemoglobinaemia and other forms of nitrogen, like nitrite are considered to be potentially carcinogenic. Nitrogen also causes significant environmental impacts in form of ammonia by land spreading of slurry.

Phosphorus is the second main pollutant, because it may cause eutrophication in surface water bodies (Hubbard et al., 2004). The pollution of phosphorus may be caused by runoff to surface

water sources, when application to land is in excess of crop requirements (Knowlton et al., 2004). In the past decades, a new class of pollutants has emerged in livestock waste in the form of veterinary medicines, like antibiotics and growth promoters which also move to water sources by runoff (WHO, 2012). The pollution of this sector depends on the technology of animal husbandry.

Livestock sector is separated into two systems. The first and most effective system is indoor- (pigs and poultry), and the second, but more natural system is pasture-based (sheep and livestock) animal husbandry (Česonienė et al., 2019). Concentrated livestock breeding has been identified as a significant source of contaminations of surface water. In their study, Česonienė et al., (2019) were monitoring surface water sources, next to potential agricultural pollution sources. In their results they highlighted, that the activity of pig farms affected the surface water quality more than that on livestock farms. They reported, that as the number of animals increased on the farms, pH decreased and the quantity of suspended harmful materials increased in surface water. In another study Hubbard et al. (2004) carried out experiments to examine the impact of pasture-based animal husbandry on surface water sources. They reported, that grazing animals can affect water quality both positively and negatively. Pasture management is advantageous in protecting the soil surface from erosion, compared with conventionally produced crops, but on the other side pasture animals can affect water quality through erosion and sediment and nutrient transport to surface waters.

Erosion

The impact of soil erosion on surface water quality is not negligible. Erosion is the geological process in which earthen materials are worn away and transported by natural forces, like wind or water. On rugged surface, water erosion is inevitable, but the cultivation of sloping lands or

vegetation alteration accelerates this natural process. Soil erosion prevails mostly on sloping areas.

The main factor that cause soil erosion is poor land management which causes damage to the soil and results water runoff, instead of adequate infiltration (Liu, 2016). Soil erosion firstly causes soil loosening on the affected area, than, after the transport of soil, deposition means the main problem, especially in surface waters. These processes usually result in the relocation of top soil, which is rich in nutrients. Pollution of nearby waters and the reduction in cropland productivity are the direct consequences of soil erosion process (Issaka et al., 2016).

Not only nutrients from eutrophication are transported with erosion, but heavy metals and chemicals are also transported with soil particles, causing the disturbance of delicate aquatic ecosystems (Bing et al., 2013). The first visible consequence of erosion on surface waters is the suspending sediment, but the most harmful are not the visible factors, but rather the invisible ones, when water becomes unsafe for human consumption, irrigation, recreation and livestock activities, because of the above mentioned toxic substances (McCool et al., 1990).

Existing and conceivable solutions

It can be determined from the above, that almost all interventions of agriculture has a negative influence on water sources. Because of that, it is really important to preserve the good chemical, physical and biological quality and quantity of surface and subsurface water sources.

In Hungary, “123/1997. (VII. 18.) Government Decree - regulation on the protection of water bodies, long-term water bodies and water installations for the supply of drinking water” regulates the usage of water sources. The regulation determines hydrogeological protection zones, based on the access time of precipitation, in order to protect water resources from precipitation delivered harmful substances, derived from human activities, like agriculture.

Besides that, it determines the range of activities that can be performed within the zones. Another important regulator, to preserve the biodiversity and purity of water sources is the National Agri-Environmental Program, which aims to keep off vulnerable areas - like water sources - from agricultural utilization, based on the principle of the land use pyramid (Ángyán et al., 1999). Environmental policy principles are also important to regulate agricultural activities and pollutant emissions. These are the prevention-, partnership-, subsidiarity- and the polluter pays principles.

The amount of fertilizers, pesticides, and other chemicals, and the time of their application is also laid down in laws and government decrees.

Beside legal regulation, scientifically based good agricultural practice is also very important in the protection of water bases. There are a number of advanced agricultural technologies, in order to avoid the pollution of water sources, but the Hungarian practice shows, that financial resources are not always available to make investments in order to avoid pollution.

Conclusion

Taking everything into account, it can be stated, that agricultural interventions often have polluting effects on water bodies. Based on the above considerations, harmful substances of chemical interventions, like fertilization, chemical plant protection and veterinary preparations in animal manure pose the greatest threat on the environment and human health, as they enter the surface and subsurface water sources. Irrigation can also have negative effects on water by causing salinity rise and by mobilizing nutrients and other substances, just like soil erosion which also plays role in sedimentation of water bodies. It becomes more common, that the values of harmful substances exceeds the prescribed limits in waters. There are many studies dealing with the harmful effects of agricultural interventions on water resources. Because of

seeing water resources becoming more and more polluted with macro- and micro-pollutants, it became an urgent research field. There are a number of studies and researches investigating the contamination content of agricultural close-up water resources and the effects of these substances, but as far as I am concerned it would be expedient to perform further to assess the impact of agricultural activities on surface and subsurface water resources, taking the progress of global climate change into account, because it may have serious effects on both agriculture and water supply.

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INTERNET1: https://www.worldometers.info/hu/

INTERNET 2: https://www.drv.hu/ivoviz-minosegi-parameter-hatarertekei-es-jellemzoi