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Review

ADVANTAGES AND DISADVANTAGES OF IRIGGATION: FOCUS ON SEMI-ARID REGIONS

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The main goal of this study was to present positive and negative influences of irrigation process, as one of the widespread applied method in the melioration. High population growth demands high food production and thus stimulates modern massively agricultural economy. Irrigation as remarkable measure from ancient time and recently became over exceed, and these concomitant negative influences should be reduced or escaped. This publication is a survey of appropriate and sustainable irrigation methods based on the improvement of ecological conditions and optimizing the use of land and water resources. Water deficit is especially expressed in semi-arid regions and requests rational use of water. Thereby, macrophytes, as well known intermediates in water purification are presented in cleaning of municipal and drainage water with the aim to enable reuse of that water again in irrigation or plumbing. Bio-engineering infiltration constructions (BIC) and floating bioplato with macrophytes are indicated as environmentally sustainable and economically suitable methods in wastewater treatment peculiarly in a semi-arid area suffering from drought.
Key words: water reuse, collector drainage system, macrophytes, bio-engineering infiltration constructions (BIC), floating bioplato, Uzbekistan.

Prednosti i nedostaci navodnjavanja: poseban osvrt na semiaridna područja. Cilj ovog rada bio je predstaviti pozitivne i negativne utjecaje navodnjavanja, kao jedne od vrlo često primjenjivanih metoda melioracije. Intenzivan rast stanovništva zahtjeva visoku proizvodnju hrane i na taj način potiče masovnu modernu poljoprivredu. Navodnjavanje je značajno od početka civilizacije,ali je postalo pretjerano te popratne negativne utjecaje treba smanjiti ili izbjegavati. Ovaj rad predstavlja pregled odgovarajućih i održivih metoda navodnjavanja s ciljem poboljšanja ekoloških uvjeta i optimalnog korištenja zemljišta i vodnih resursa. Manjak vode naročito je izražen u semiaridnim područjima i zahtijeva racionalno korištenje vode. Pritom su makrofiti, kao poznati posrednici u pročišćavanju vode, prikazani prilikom tretmana komunalnih i drenažnih otpadnih voda čime se omogućuje njihovo ponovno korištenje u navodnjavanju ili vodoopskrbi. Bioinženjering-infiltracijske konstrukcije i plutajući bioplato s makrofitima pokazali su se kao ekološki održive i ekonomski prihvatljive metode u pročišćavanju otpadnih voda posebno u semiaridnim područjima s malo oborina.
Ključne riječi: ponovna upotreba vode, drenažni sustav kanala, makrofiti, plutajući bioplato, bioinženjering-infiltracijske konstrukcije, Uzbekistan.

HISTORICAL BACKGROUND OF IRIGGATION

Agriculture heralded the era of development of human civilization and irrigation process is an age-old practice almost old as human's first attempt at crop cultivation. The beginning of agriculture revolutionized lifestyle of ancient man who was only on hunting and food gathering.

Human civilization grew up near natural water resources and there are many records of the practice of irrigation from rivers and man-made channels, wells and tanks. Irrigation began at 6000 BC in Egypt and Mesopotamia (present regions of Iraq and Iran) using the water of the flooding Nile and Tigris/Euphrates rivers. The flood waters, retain from July until December, were diverted to fields for 40 to 60 days. Furthermore, by excavation of the ruins of Mohenjo-Daro civilization, in the Indus-valley (present eastern Pakistan), flourished and reached its peak in 3000 BC, illustrate the existence of a network of well-designed water supply and drainage systems [1]. Primary agriculture including mainly food production changed slowly to the fast modern agriculture with high economical purpose and continuous evolution of technologies.

Climate, soil and water are three basic natural resources which decide the nature, scope and extent of successful crop cultivation. Climate determines the availability of water resources and the type of crops, because the main concern of productive agriculture is to have adequate, effective and efficient supply of water. Due to the huge population growth concomitant with development of industrialization and economy there are many negative anthropogenic impacts on water bodies, i.e. increasing inflow of municipal and industrial wastewater, leaching soil and fertilizers from agricultural fields, damming, recreational activities [1]. Maldistribution of rainfall in most regions also can make irrigational water scarcity. Moreover, a large amount of water is wasted in conveyance and distribution systems where lining of channel has either not been undertaken or has been ill-maintained. Improper irrigation scheduling, land grading and levelling and faulty method of irrigation lead to waste of water. Two situations may arise in deciding the course of water management: 1) the arable land is large in comparison to the water availability and the objective of efficient water management would be maximize through the crop production per unit of water and 2) when the land is limited as compared to available water, the intensive agricultural approach could be useful to increase productivity per unit of land [2].

IRRIGATED AREA IN THE WORLD AND IN SEMI-ARID CLIMATE: AN UZBEXISTAN EXAMPLE

Irrigation systems are essential in areas of low rainfall, and water is obtained from surface and ground water. Rivers, lake and reservoirs constitute the sources of surface water. Dams across rivers diverted water to agricultural fields through the distributaries channels governed by gravity flow (Fig. 1a). In the case when the river is on lower level then fields, water is pumped up (Fig. 1b). Underground water supplies recharge by seepage of surface waters and percolating flood. In this type of irrigation scheme ground water is pumped by means of electrical or oil driven pumps and is provided for irrigation (Fig. 2).

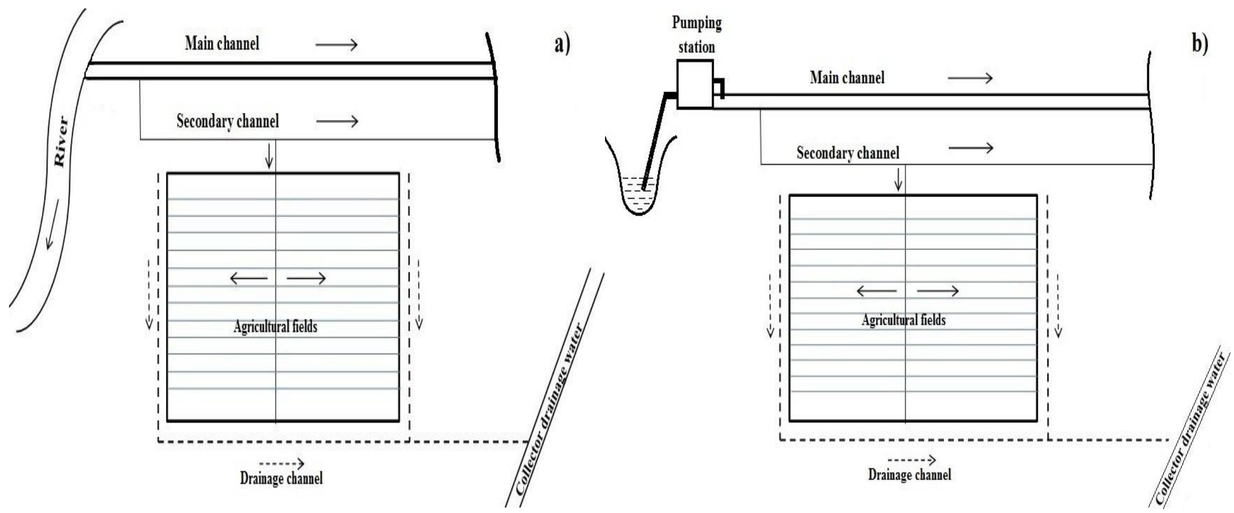

Figure 1. Scheme of irrigation by gravity for equal (a) and by pumping at different (b) altitude level of water and field
Slika 1. Shematski prikaz navodnjavanja gravitacijom za jednaku (a) i pumpanjem (b) za različitu razinu vode i navodnjavane površine

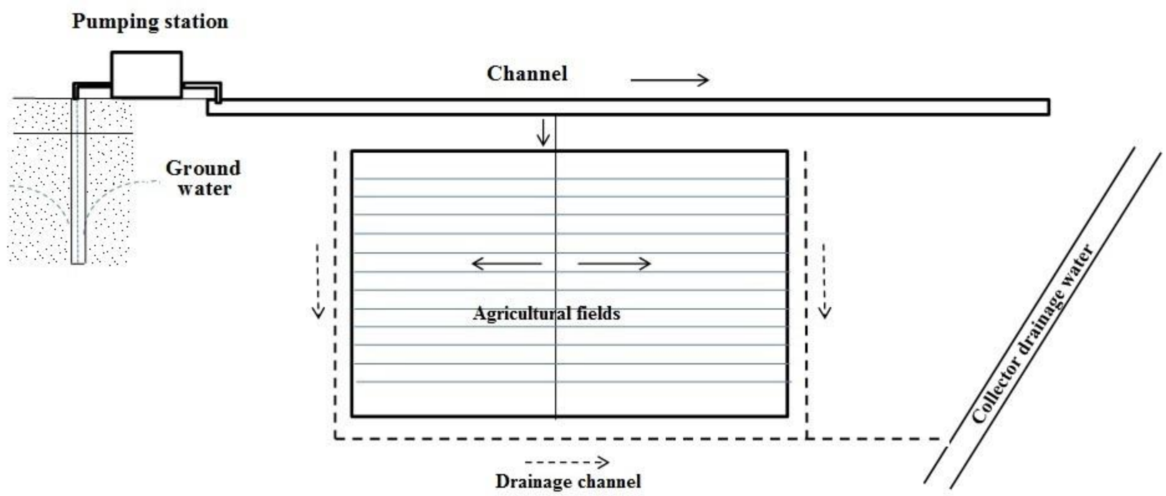

Figure 2. Scheme of underground water use for irrigation
Slika 2. Shematski prikaz korištenja podzemnih voda za navodnjavanje

Recently, climate changes caused by global warming impact the water availability and water demands in agriculture. Temperature increase, sporadic rainfall events, increase of evapotranspiration connected with global warming thus affect reinforced application of irrigation [3]. About 69% of the total area equipped for irrigation is located in Asia, 17% in America, 8% in Europe, 4% in Africa and 2% in Oceania (Table 1).

Table 1. Contribution of irrigation area over the continents. Non-conventional sources consider treated wastewater and desalinated water
Tablica 1. Udio navodnjavanja na pojedinim kontinentima. Nekonvencionalni izvori podrazumijevaju vode nakon pročišćavanja i desalinizacije

Continent	Total area intended for irrigation $\times 10^4$ km^2	Area equipped for irrigation $\times 10^4$ km^2			Area actually irrigated $\times 10^4$ km^2
		With ground water	With surface water	Non-conventional sources	
Africa	13.54	2.51	11.02	0.01	11.52
America	51.33	24.29	27.08	0	41.33
Asia	213.72	80.76	132.75	0.22	186.68
Europa	24.33	7.49	16.83	0	12.56
Oceania	4.69	1.13	3.48	0.07	3.07
World	307.63	116.15	191.18	0.29	255.18

On the country level great share in irrigation belongs to China (62.4×104 km^2), India (61.9×104 km^2) and the United States of America (28.4×104 km^2) [4].

Agriculture in Uzbekistan was and still is the largest sector in country's economy. Cotton and wheat are the major crops in Uzbekistan. About 60% of the country is semi- desert with only 4×10^4 km^2 of irrigated area for the year 2007. Agricultural production in the country, like in the whole of Central Asia, is predominantly based on irrigation, which makes water resources and management as the major factors limiting crop yields in the region. Water resources of Uzbekistan are the part of Aral Sea region with main rivers Amu Darya and Syr Darya as well as ground water (Fig. 3) [5]. Mean annual runoff of both rivers amounts up to 133.6 km^3, a share of Uzbekistan is approximately 50%, including 62 km^3 for irrigation and 11 km^3 for other purposes [6].

Figure 3. Map of Uzbekistan with marked Karakalpakistan and Khorezm region with constructed wetlands
Slika 3. Karta Uzbekistana s označenim područjima Karakalpakistan i Khorezm u kojima su postavljene umjetne močvare

THE ROLE OF MACROPHYTES WETLANDS IN THE IRRIGATION PROCESS

Macrophytes are defined as macroscopic photosynthetic organisms including algae, mosses and vascular vegetation which are also able to adapt to live in aquatic environments [7]. Their density influence water biochemistry and ecology of ecosystems. For instance, they prevent resuspension of sediments and therefore dynamics of nutrients (mostly nitrates and ortho-phosphates), offer a shelter from predators, as well as abundant and diverse food resources and considering high diversity of species and habitats [8, 9]. Macrophytes steam and especially root systems are habitats of very intense microbial activities and thus important in organic matter degradation and mineralization [10]. In this review macrophytes role was considered in the view of reuse of wastewater after treatment through macrophytes wetlands with special focus on the treatment of drainage waters with the purpose of their reuse for irrigation.

Nowadays, the best policy for preventing the pollution and moderate management of water resources consists in efficient water treatment at local levels. Bio-engineering technology of water treatment for small settlements is economical, needs low investments and maintenance costs and lower requirements as regards the qualifications of the personnel. One option on that course are artificial (constructed) wetlands, an engineering constructions planted with natural vegetation. They have been developed in many countries (USA, Germany, Russia, Switzerland) in the wastewater treatment because of multiple positive effects, for instance decrease concentration of organic matters and nutrients (NH_4, NO_2, NO_3, PO_4), oil, pesticides (DDT, lindane), trace elements with the aim of water quality improvement [11].

Few experiments connected with macrophytes and artificial wetlands were conducted from 1991 to 1995 in the laboratory of the Scientific Consulting Centre ”ECOSERVICE”, Tashkent, Uzbekistan. There were developed and constructed riverbed and floating bioplato with macrophytes (Fig. 4, 5, 6), which showed high efficiency in removing pollution few days after installation [12]. A proposal for constructed wetlands was developed and prepared for bio-engineering technology applied in field conditions for treatment of collector-drainage water on the grounds of the laboratory experiments. They mainly used five macrophytes species in the water treatment: *Phragmites communis*, *Typha angustifolia*, *Typha latifolia*, *Scirpus lacustris*, *Acorus paludis.*

For small settlements drinking water supply bio-engineering infiltration structure (BIC) with macrophytes was installed in Karakalpakistan, in semi-arid northwest of Uzbekistan from year 2000 until now (Fig. 4) [13]. For the filter layer gravel, crushed stone, sand and sandy loam have been used. Water purification efficiency depends on the contact time between water and macrophytes. Water residence time of 1 to 5 days suggested that the water quality after the BIC treatment was improved from high saprobity to oligosaprobity. The concentrations of total nitrogen, phosphorus, organic substances were reduced 10 to 100 fold. Chemical analyses have shown that 22 – 38% of organic contaminants were removed in the waterbody of the BIC, and the remaining 62 –78% in the filter zone by the biological activity of the macrophytes and biocenosis (Table 2) [11].

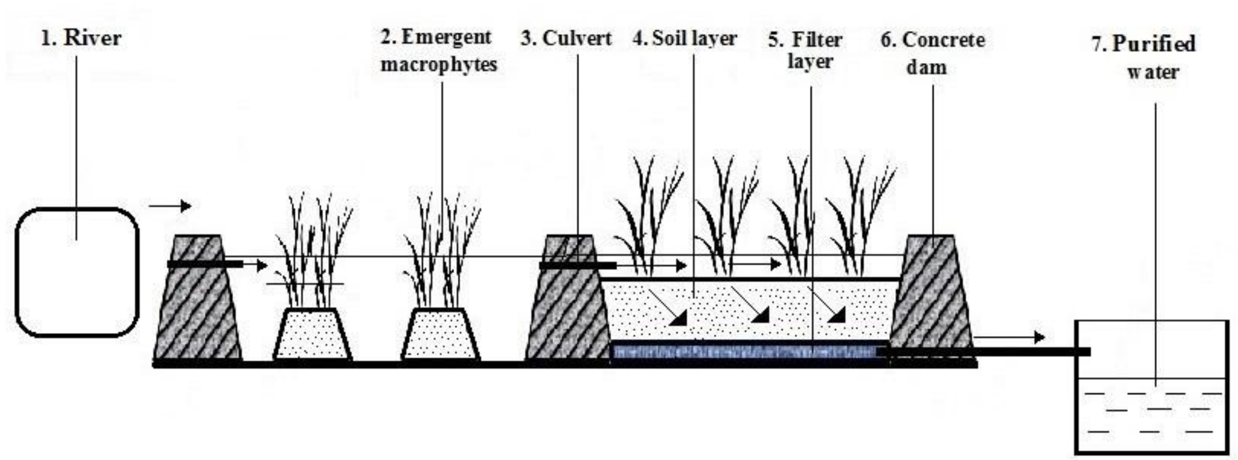

Figure 4. Scheme of bioengineering infiltration construction (BIC) cleaning with macrophytes. Arrows sign water flow

Slika 4. Shematski prikaz bioinženjering infiltracijske konstrukcije s makrofitima. Strelice označavaju smjer strujanja vode

Table 2. Removal of organic matters and ions from the water reservoir during the retention time of 3 days in the bio-engineering construction (BIC), with the purpose of using as drinking water

Tablica 2. Uklanjanje organskih tvari i iona iz vode u rezervoaru, nakon trodnevnog zadržavanja u bioplatu s makrofitima, u svrhu korištenja kao vode za piće

Parameters	Inflow	Outflow
	Removal (%)	
BOD_5	54	88
COD	52	83
NH_4^+	66	89
NO_2^-	73	98
NO_3^-	68	84
PO_4^{3-}	63	89
Suspended solids	70	95
Fe	81	87
Cu	64	93
Zn	93	99
Pb	70	94
Cr	98	99
Cd	99	100
Mn	97	100

Floating bioplato constructions were used in drainage channel with the purpose to prevent soil erosion and for improvement of water quality (Fig. 5). In the area exposed to the salinization and soil erosion problems floating bioplato construction was set up with common rush vegetation to protect erosion of sandy coast. In small collector drainage channels (width$_{max}$ 5 m), artificial wetlands with macrophytes were used in the length off ca. 15 m and area of 50 m^2 situated in Horezm region, semi-arid northwest Uzbekistan, from the year 1998 until now. One unit of that bioplato is consisted of macrophytes container (0.8 × 1.6 × 0.2 m) constructed from plastic pipes and wood and interconnected with reed steams. In each container were planted roots of four macrophyte species (*P. communis, T. angustifolia, T. latifolia, S. lacustris*) during the spring and after two years macrophytes achieve their maximum length with submerged and floating root system. With this method, the extraction of pollutants carried out through the direct absorption of dissolved minerals from the water by the root systems and connected biocenosis and by sedimentation of suspended matter over submerged root system of the macrophytes.

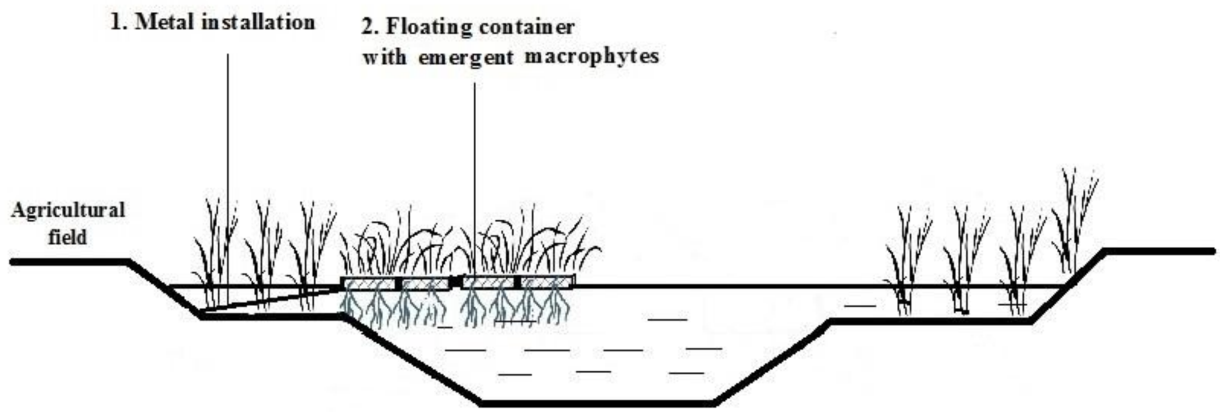

Figure 5. Scheme of transversal profile of floating coastal bioplato with microphytes
Slika 5. Shematski prikaz transverzalnog profila plutajućeg priobalnog bioplatoa s makrofitima

Riverbed bioplato can be consisted of few lotic and lentic (ponds with macrophytes) stretches in the cascade system on the longitudinal profile of the channel (Fig. 6). In semi-arid area there could be combination of saline intolerant and tolerant macrophytes, which remove also salinity besides organic matter, nutrients and trace elements. First treated water after irrigation is reused in fishpond and then again on the field [14].

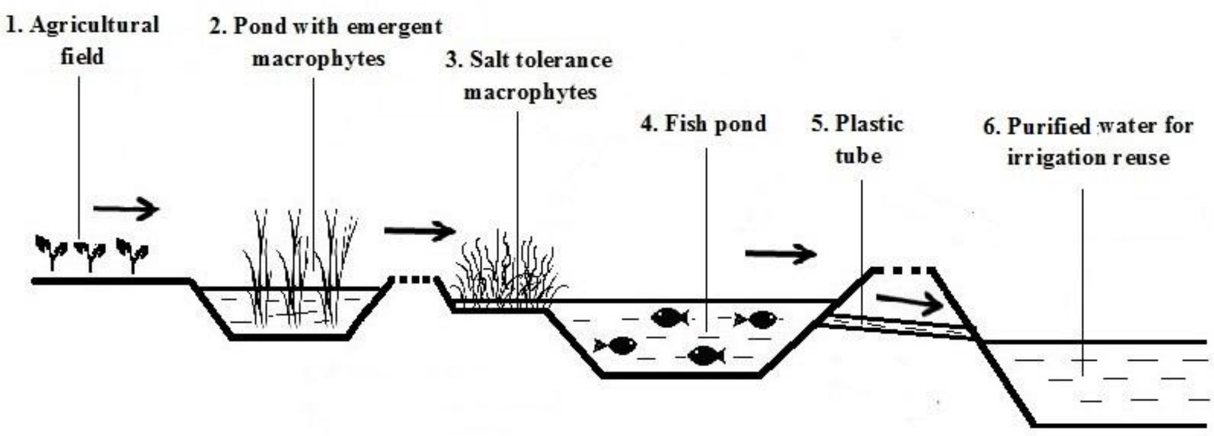

Figure 6. Scheme of longitudinal profile of drainage channel with riverbed bioplato
Slika 6. Shematski prikaz longitudinalnog profila drenažnog kanala s makrofitima

DISADVANTAGES OF EXCESS IRRIGATION

Irrigation can have large benefits, only when it is properly managed and controlled. Permanent irrigation result on the global level in reduction of downstream discharge, increased evaporation of the irrigated area, and increased groundwater recharge. Also, faulty and careless irrigation influences negative effects on crops and land, as well as causing waste of valuable water. Harmful effects for crops and environment are manifested as follow [1, 14]:

1. *Impaired soil aeration and imbalance in nutrient uptake.* Excess irrigation fills all soil pores expelling soil air completely. This leads to deficiency of oxygen in the soil and disturbs seriously the root respiration and root growth. Reduced or lack of root respiration leads to great disturbance of the nutrient uptake.

2. *Disturbance in microorganism activities*. Excess irrigation causes deficiency of oxygen in soil. Useful aerobic bacteria cannot function well in mineralization of organic matter under oxygen deficiency. Decomposition and mineralization of organic matter, atmospheric nitrogen fixation and availability of nutrients to plants are hampered. On the other hand, anaerobic bacteria are activated by denitrification i.e. nitrates (NO_3^-) reduction to the nitrogen in the gas form (N_2) and production of intermediate harmful gases, nitrogen monoxide (NO) and nitrous oxide (N_2O).

3. *Rise of water table*. This occurs particularly in lands where the root zone is underlain by an impervious soil or rocky layer. Faulty and over-irrigation leads to rise of water table where restricts the root and feeding zones of crops. Growing of fruit trees and deep rooted crops is very much restricted in areas where the water table rises high up and gets near to the soil surface. Roots do not grow in wet soils and usually remain shallow particularly where water table rises and encroaches the normal root zone of crops, and thus restricted availability and uptake of nutrients. Consequently, crop growth and yields are affected.

4. *Toxicity of nutrients*. Under excess soil water condition and in water logged soils, some nutrients like manganese and iron get reduced in the soil, consequently

their solubility increases and leads to their toxic effect on plants.

5. *Production of harmful gases***.** Under excess soil water and water logging conditions harmful gases such as ethane, methane, hydrogen sulphide, carbon monoxide and hydrogen gas are produced due to anaerobic decomposition of organic matter present in the soil. These gases are toxic to crops and plants become stunted and diseased.

6. *Loss of soil fertility*. Uneven and excess irrigation leads to leaching of nutrients beyond plant root zone. Often, careless and heavy irrigation causes erosion of fertile surface soil and runoff that washes out plant nutrients into drains.

CONCLUSION

In this article main principles of irrigation, role of macrophytes in wastewater treatment and macrophyte artificial wetlands are reviewed. Constructed wetlands recently are very often applied in the wastewater treatment overall the world. Purification of drainage and wastewater with biological and bio-engineering methods notified effective results in the short period, eg. few days, with the aim of water reuse in irrigation or plumbing. Beside direct impact on water purification, artificial wetlands support species and landscape diversity and, considering low energetic demands, sustainable development, and play an important role in many ecological restoration concepts. However, exceed irrigation leads to many harmful effects for crops and environment, i.e. deterioration of nutrients uptake by plants, toxicity of some molecules, and hydrological deteriorations. Properly managed and controlled irrigation is useful in the agriculture and it can have large benefits. Artificial wetlands in drainage channels are potentially key treatment for better reuse of irrigated water and ecosystem sustention and conservation.

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