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Water Quality Protection in Lake Kinneret-Long and Short-Term Perspectives

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Introduction

As the only multipurpose natural freshwater Lake in Israel, Lake Kinneret management is a national concern. Cornerstone events in the History of the lake and its drainage basin management include: 1933-construction of a Dam on the River Jordan outlet; 1964 -inauguration of the National Water Carrier which removed daily about one mcm (million cubic meters; 10^6 m^3); 1967-Operation of salty waters (about 20 annual mcm with about 40,000 ton) removal system; 1994- Harmful Cyanobacteria (HFCB) invasion and domination decline of the bloom forming Peridinium spp.; 1980`s trophic status shifting from Phosphorus to Nitrogen limitation; 2010-National supply of desalinized water for domestic demand and consequently diminished of Kinneret withdraw; A brief consideration of the implementation of Limnological principles within management design of combined utilization and quality protection in Lake Kinneret is presented.

Dam Operation

Some of the Kinneret Hydrological parameters assembled with respect to the impact of climate condition changes on the hydraulic trait of Lake Kinneret (Tables 1 and 2).

Year	Annual Mean WL (mbsl)	Annual Water Input (mcm/y)	Annual Mean Lake Volume (mcm)	HRT (years)
1969	208.87	1099	4471	4.1
1992	209.32	842	4302	5.1
2001	214.11	254	3484	13.7
2015	212.45	141	3822	27.1
2019	211.54	160	3986	24.9

Period	Mean Lake Volume (mcm) (10^6 m^3)	Annual Mean of water input (Jordan River) (mcm/y)	HRT (years)	Periodical WL amplitude (mbsl)
1988-1991	4217	358	11.8	210.40-208.89
1995-2003	4059	338	12	211.06-209.72
2005-2010	3823	381	10	210.86-212.66
2014-2019	3660	235	15.6	212.84-213.36

Mean WL: The average between Highest and Lowest recorded WL.

MBSL: Meter below Sea Level (Lake Kinneret is located below sea level)

MCM: million cubic meters (106 m^3)

HRT is defined as the ratio between water input and lake volume un-affected by water level.

Utilization of Desalinized Waters

Recent proposals of the Kinneret hydrological management are aimed at enhancement of water supply for irrigation in the Hula

Valley (northern to lake Kinneret), to the state of Hashemi Jordan, to Eastern part of Israel (Arava Valley), and to the West-Bank. A recent implementation of an annual addition of 60 - 100 mcm desalinized water to the lake create an agro-limnological dispute: direct desalinized water into lake Kinneret and pump lake water for agricultural demands in the Hula Valley or direct desalinized water for irrigation not through the lake. There is a significant hydro-limnological and financial difference between these two management options. The evaluation of limnolgical principles is required in order to maintain a setting between those two controversial implementations: the difference between long-term (multiannual) and short-term (annual or seasonal) modifications within the ecosystem structure. Taking Kinneret water salinity as an example, the following background conditions are consider: most of the salt import into Lake Kinneret originate from sub-lacustrine uncontrolled sources and salinity of runoffs is lower by order of magnitude from that of the lake. Consequently, short-term seasonal changes of salinity are decline during winter floods and increase later. Nevertheless, in spite of seasonal concentration decline resulted by winter floods, the total load capacity is increasing (Figure 1). Not like salt concentration, its load inventory is not fluctuate (ups and downs) by seasonal water balance changes and continually increase or stay high unless reduced by pumping or through open dam release. The limnological consequence of pumping or open dam release is control implementation of the water exchange rate defined as shortening of the Hydraulic Residence Time (HRT). Future perspective of long term Kinneret water quality protection is therefore include both input of desalinized water and pumping lake water as an additional supply to the Hula Valley and/or other consumers. Three advantages are consequently achieved: shortening of HRT, decline of total salt load capacity, additional water allocation to the Hula Valley and other consumers, and financial conditions improvement. Nevertheless, an optional disadvantage is also predicted: salinization enhancement of the Peat-Soil in the Hula Valley. Conclusively, water managers should consider the balance between soil salinization risks versus prevention of lake water long-term deterioration. Elimination of the soil salinization deterioration is already carried out successfully, since early 20th century, by farmers cultivating field and grove crops in close vicinity to the Lake Kinneret. Since the early 20th century, vast area is efficiently cultivated by Lake Kinneret water irrigation. Partial soil salinization is routinely treated by freshwater flushing. This case exemplify an optimal combined implementation of limnology, agriculture. Financial merit and human welfare.

Hydro-limnological Test cases

If the rate of discharge is enhanced. HRT become shorter. Nevertheless, shortening of HRT occur also by lake water release (open dam) or pumping withdraw. Since the Mid 1980`s changes of climate conditions in the Watershed of Lake Kinneret were documented: precipitations and river discharges decline, and temperature elevation. Relevant recent hydraulic cases in Lake Kinneret are implicit to comparable management under alternates of droughts and floods along the history of Lake Kinneret. During the heavy rainfall in 1969 and 1992 the Dam was open and close respectively. Similar quantities of water input, app. 1 billion m^3 flew into the lake during the winter months in 1969 and 1992. But, in 1992 HRT was longer because the Dam was closed and lake volume increased. Moreover, Winter salinity declined by 64 ppm (300 to 236) and 39 ppm (250 to 211) during 1969 and 1992 respectively. It is therefore concluded that seasonal salinity concentration might be even enhanced by close dam (smaller dilution resulted by lower decline) and longer HRT as shown for 1992 dam management case. During 1948-2020 five temporal periods of increased salinity were indicated: 1948-1968, 1988 – 1991, 1995 – 2003, 2005 -2010 and 2014 – 2019. Whilst decline was recorded during 1964 – 1988 resulted by the salty springs removal together with the heavy flood event. The salty springs removal, refer to annual discharge of 20×10^6 m^3 and total salty load of app. 40,000 tons. It is therefore suggested that significant increase of salinity during 1948-1964 (from 275 to 396 ppm) is due to close Dam policy which resulted HRT prolongation, WL increase and enhancement of salt concentration and load.. The salinity elevation afterwards were probably affected mostly by water balance resulting HRT fluctuations. Results given in Table 2 indicates the irrespective relation of HRT prolongation to WL (i.e. Lake Volume) but positively correlated with water balance [1-3].

A Brief Modelling Highlight

Two models (abbreviated as: A and B) of salinization process dynamics in Lake Kinneret were defined: A model attributed salinization dynamics to geo-hydrological dynamics of the interphase contact between underground salutes and water flows in the aquifers. The B model rely on the major function of water balance. The A model did not evaluate data collected before 1960 and the B model verify field data before 1960. It is suggested that B is well adapted to short-term (days and weeks) prediction when great runoff inputs enhance decline of lake salinity, whilst for long-term period (months and years) when water retention time is long, additional water migration through aquifers initiate salinity elevation as predicted by A model. According to B, reduction of runoff inputs implies salinity increase and A indicates that increase of salinity is the result of water yield enhancement in the aquifers (enhanced by runoffs). The original Kinneret salinity probably ranged between 250-350. Salinity fluctuation has probably lesser impact on the biota (flora and fauna) of Lake Kinneret. The phytoplankton is highly vulnerable to nutrient availability changes and to a lesser extent to salinity per se. It is not impossible that freshwater algae might be adapted to salinity changes of ups and downs but the amplitude ranges has not definition yet, as well as salinity decline. Kinneret salinity was lowered from 400 ppm in 1967 to 200 ppm during the early 1980's, and the phytoplankton composition was fairly stable and significant change came 30 years later when Nitrogen deficiency and N/P mass ration was developed. Then, the domination of the bloom forming Peridnium spp. diminished and Harmful Cyanobacteria enhanced. To achieve reasonable protection of Lake Kinneret ecosystem, an outlined target of salinity below 350 ppm is accepted. If the usage of the Kinneret waters would be mostly directed towards agricultural irrigation, it is probably cheaper to control salinity by the less expensive operation of hydrological conditions than the expensive processes of salts removal.

One Year test case that was documented by Mekorot, National water Supply Company, Laboratory and Kinneret Watershed Unite in an interim annual report: October 2018-October 2019 is given here in (Figure 1).

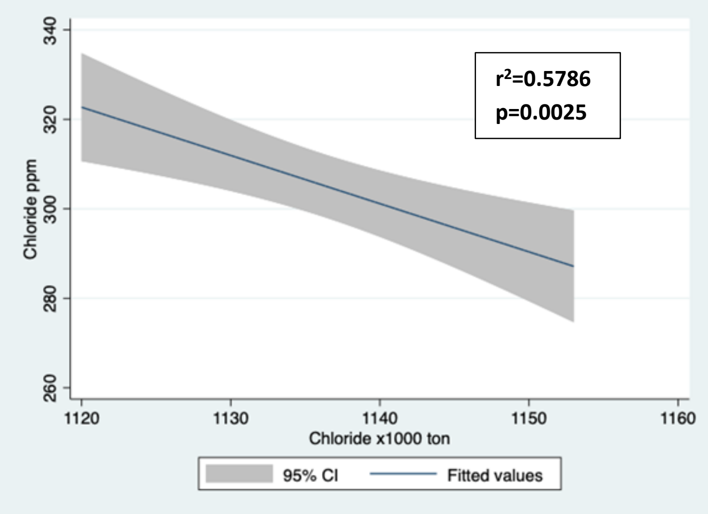

Figure 1: *Linear regression (95% Ci and regression parameters are given) between monthly means of Chloride concentration (ppm) and Total load (tons) in Lake Kinneret during October 2018 – October 2019.*

This Information indicates the followings: during winter months (short-term) Chloride concentration was lowered by 39 ppm whilst documentation of annual (long-term) change represent an increase of 36,000 tons of salt lads to loads in Lake Kinneret. This conservative load would enhance salt accumulation in the Lake unless partly removed through pumping or Dam spilling. Nevertheless, total annual pumping withdraw was 136.2 mcm (10^6 m^3) which is about three times lower than earlier removals. The annual natural evaporation of pure water that was estimated as 254.3 mcm has no impact on the lake load.

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