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Analysis of the use of selected reservoirs in the Wielkopolska province

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Abstract: *Analysis of the use of selected reservoirs in the Wielkopolska province.* The paper presents characteristics of six selected retention reservoirs located in the Wielkopolskie province, i.e. the Radzyny and Przebędowo reservoirs located near the city of Poznań, the Miedzichowo reservoir situated at the western border of the province, as well as the Stare Miasto and Jutrosin and Pakosław reservoirs, situated at the eastern and southern parts of the province, respectively. The paper also presents results of studies concerning water quality parameters in the selected reservoir of Przebędowo (at the inflow, within the reservoir and at the outflow) for the example year of 2016. The greatest water area of approx. 110 ha and at the same time the greatest capacity (2.88 million m^3) at normal level damming (NLD) was found for the Radzyny reservoir on the Sama river, constructed in 2000, whereas the smallest water area (5.3 ha) and the smallest capacity (0.1 million m^3) at NLD were recorded for the Miedzichowo reservoir, which was constructed in 2013. Apart from the positive aspects related to the operation of water storage reservoirs we frequently observe problems with their operation and use. In the winter periods they are mainly connected with the so-called icing, which has a negative and often destructive effect both on the condition of reservoir dams and on their banks. In turn, in the summer months a common problem in the operation of reservoirs results from obstruction from vegetation accumulated on the damming structures, which frequently reaches the dams particularly in periods characterised by high daily precipitation totals. Another common problem in terms of the operation of retention reservoirs is also related with the process of their eutrophication, connected with the influx of biogens. Analyses of selected water quality indexes for the Przebędowo reservoir showed, particularly in relation to nitrates and nitrites, their higher values at the inflow to the reservoir, indicating a considerable effect of land use in adjacent areas primarily in terms of fertilisation and the resulting runoff of biogens to the watercourse supplying the reservoir.

Key words: water management, retention reservoirs, water quality

INTRODUCTION

According to Kundzewicz (2000) and Kundzewicz et al. (2010) in Poland we face all the three categories of water-related threats. Problems with the destructive excess waters are experienced occasionally, those resulting from water shortages are much more common, while those caused by inferior water quality are prevalent. According to those authors urban floods are becoming increasingly dangerous in Poland (as it is impossi-

ble to drain large amounts of rain water from urbanised areas), as evidenced by the considerable losses they have caused in recent years. In turn, as it was reported by Ryszkowski et al. (2003), droughts are a grave problem particularly in the Polish Lowlands.

Within the framework of the small retention programme implemented since the mid-1990s, attempts have been made to prevent these extreme phenomena e.g. thanks to water storage reservoirs constructed both within the river continuum (dammed reservoirs) and outside it (lateral reservoirs).

Their role is typically connected with water retention, its use by municipal utility companies, industry and agriculture, flood control, recreation and energy generation.

It needs to be stressed that apart from the obvious positive aspects, water storage reservoirs frequently cause problems related with their use and operation both in the winter and summer months. In terms of the optimal operation of such reservoirs the process of their eutrophication poses considerable problems. As it was reported by Gruca-Rokosz et al. (2011), water eutrophication is caused by the influx of nitrogen and phosphorus compounds from the catchment, resulting within this ecosystem in the accumulation of primary and secondary products of photosynthesis, which due to oxygen deficit in the pelagic zone fail to be decomposed. This process contributes to a reduction in reservoir capacity and thus leads to a deterioration of their utility value.

The aim of this paper is to present characteristics of selected retention reservoirs located in the Wielkopolskie province, the functions they serve in the water management in the region as well as problems related with their operation.

MATERIAL AND METHODS

The Wielkopolskie province is situated in central-western Poland (Fig. 1) and is one of the largest among the 16 provinces in Poland. It is 29,826 km^2 in area (9.5% territory of Poland).

According to the physico-geographical regionalisation of Poland (Kondracki 2000) this province is located within two subprovinces: the South Baltic Lake Districts and the Central Polish Plains, i.e. areas coded (314–315) and (318). A characteristic feature of the South Baltic subprovinces is connected with early post-glacial landscapes with a large number of terminal depressions and lakes connected with the process of glacier ice waning embedded in the glacio-fluvial moraine material, while we distinguish undulating morainic and outwash plateaus. In turn, in the Central Polish Plains the landscape is dominated by lake-free denudation plains composed of glacial tills, sands and periglacial cover with gravel relic remnants of moraines and kames of older glaciations (the Riss and Warta glaciations), separated by river valleys and basic depressions.

As it was reported by Woś (1993), the Wielkopolska region is located in the transition zone between the oceanic and continental climates, with polar-maritime advections being predominant air masses. The influx of this humid air reduces the amplitude of tempera-

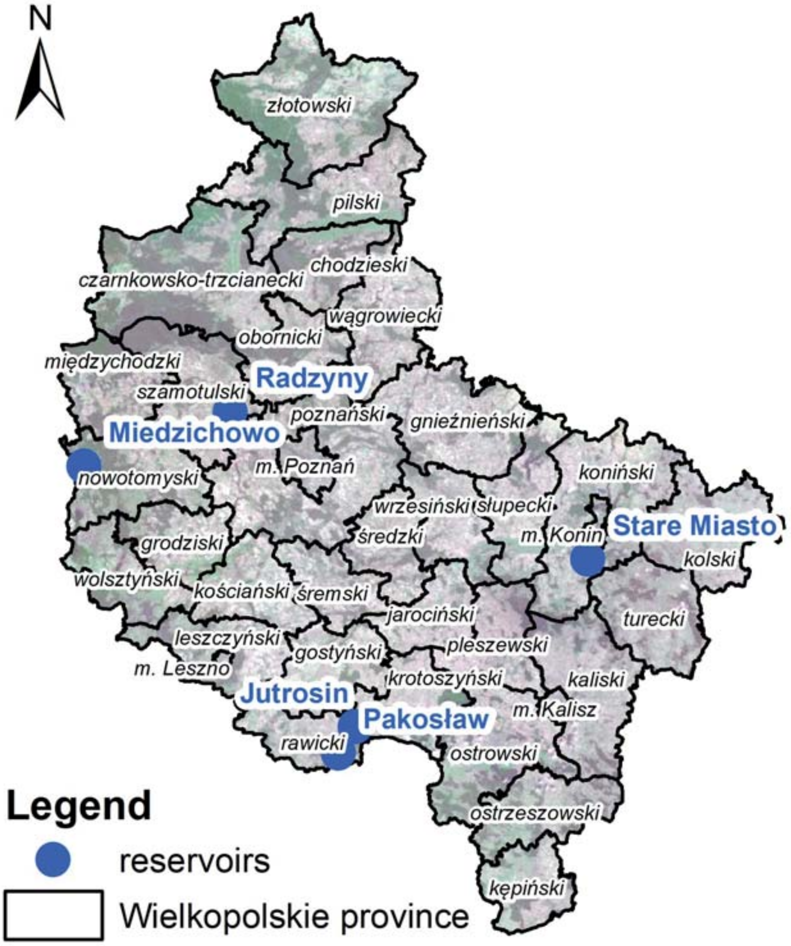

FIGURE 1. Reservoirs location in the Wielkopolskie province

tures, brings overcast and more abundant precipitation. Winters are shorter and milder, while the vegetation season typically begins earlier and lasts longer than in the regions of eastern and central Poland. Mean annual precipitation total in the analysed area ranges from below 500 mm for Śrem to over 600 mm locally in the south and west of the region, as a result making it one with the greatest water deficits in Poland.

According to the prepared Programme of Small Water Retention in the Wielkopolskie province for the years 2016–2030, surface waters cover an area of 40,097 ha, of which standing waters account for 10,336 ha.

This paper presents characteristics of six selected retention reservoirs located in the Wielkopolskie province, i.e. the Radzyny and the Przebędowo reservoirs near the city of Poznań, the Miedzichowo

reservoir situated at the western border of the province, as well as the Stare Miasto reservoir and the Jutrosin and the Pakosław reservoir, located in the eastern and southern parts of the province, respectively (Fig. 1).

The Przebędowo, Radzyny and Stare Miasto are dammed reservoirs, while the Pakosław and the Jutrosin are lateral reservoirs. In turn, the Miedzichowo reservoir was constructed at the site of an older one, which as a result of long-term neglect was silted-up and completely overgrown.

Table 1 presents basic parameters of the Radzyny reservoir composed of two reservoirs separated by a dam, which were characterized jointly as a whole.

This study also provides testing results for water quality parameters in the Przebędowo reservoir for an example year of 2016. Water samples for analyses were collected at the inflow to the reservoir, within the reservoir and at the outflow, while the results were characterised based on the Regulation of the Minister of the Environment of 21 July 2016 on the classification of the status of bodies of water and environmental quality standards for priority substances.

RESULTS AND DISCUSSION

In the Wielkopolskie province there are 38 reservoirs and permanently dammed lakes, until 31 December 2017 administered by the Wielkopolska Board of Land Amelioration and Hydraulic Structures in Poznań. As a consequence of changes in the Water Act and the establishment of a new entity responsible for water management in Poland, these reservoirs starting from 1 January 2018 became the property of the State Water Management Authority.

Apart from the agreements of 1995 and 2002, which initiated the construction of retention facilities in Poland, their versions updated in the following years were crucial. For the Wielkopolskie province in February 2005 the existing programmes were updated and the Programme of Small Water Retention for the years 2005–2015 was developed both in the hydrographic catchment system and in terms of the administrative division, i.e. for counties and communes. This Programme was approved by the Province Board and the Wielkopolskie Provincial Assembly. It was also approved by the Ministry of Agriculture and Rural Development, the Regional Water Management Boards in Poznań and Wrocław, as well as the Department of the Environment and Agriculture of the Wielkopolska Provincial Office and arranged with the respective communes and counties.

That programme stressed the need to increase water resources in catchments of primary watercourses in the Wielkopolskie province, which results from the climate conditions characterised by the frequent incidence of drought spells.

The analysis confirmed that the province in the period until 2015 had the potential for the construction of a total of 48 dammed lakes, 62 valley reservoirs, 230 damming structures and 282 village ponds. It needs to be stressed here that the analysed reservoirs were constructed within the framework of the above-mentioned programmes, with the Miedzichowo and Przebędowo reservoirs being

commissioned the latest, i.e. in 2013 and 2014, respectively.

The largest area of approx. 110 ha and at the same time the greatest capacity (2.88 million m^3) at Normal Level Damming (NLD) is recorded in the Radzyny reservoir on the Sama river, commissioned in 2000 (Fig. 2).

In contrast, the smallest water area (5.3 ha) and the smallest capacity (0.1 million m^3) at NLD are found for the Miedzichowo reservoir, which operation was started in 2013 (Fig. 3, Table 1).

Overall the total capacity of the presented reservoirs at normal level damming is 7.53 million m^3. These reservoirs serve numerous functions and needs, of which the most important include flood control (Jutrosin, Pakosław, Stare Miasto, Radzyny, Przebędowo), agriculture (Jutrosin, Pakosław, Stare Miasto, Radzyny), fishery (Jutrosin, Pakosław, Radzyny) and energy generation (Stare Miasto and Miedzichowo).

An important role played by retention reservoirs, particularly those located in the vicinity of agricultural utilised areas, is connected with the impact of water stored in the reservoirs on groundwaters in adjacent areas, thanks to the provided water supplies in drought spells. This was confirmed e.g. by studies conducted by Szafrański and Stefanek (2008) on the Mściwojów dammed reservoir, and by Przybyła and Kozdrój (2013) in their analyses concerning the Pakosław reservoir in the catchment of the Orla river.

All the analysed reservoirs, in accordance with Article 62.1 of the Building Code are covered by routine maintenance inspections (2 times a year: in the spring and in the autumn), as well as periodical inspections (1 a year) and technical condition inspection and fit-for-purpose assessment of a structure, which is performed every 5 years by authorised inspectors holding respective building licences.

FIGURE 2. Retention reservoir Radzyny

FIGURE 3. Retention reservoir Miedzichowo

TABLE 1. Basic parameters chosen reservoir retention in Wielkopolskie province

Reservoir	River	Lenght reservoir (m)	Altitude at NLD (m a.s.l.)	Capacity at NLD (million m^3)	Inundation area at NLD (ha)	Start of operation
Przebędowo	Trojanka	1 450	72.50	0.16	12.03	2014
Radzyny	Sama	5 000	72.50	2.88	109.44	2000
Stare Miasto	Powa	3 100	93.50	2.16	90.68	2005
Pakosław	Orla	720	92.40	0.33	26.60	2007
Jutrosin	Orla	2 160	98.75	1.90	90.50	2011
Miedzichowo	Czarna woda	750	61.20	0.10	5.3	2013

The main threats connected with the operation of the analysed reservoirs result among other things from the so-called icing in the winter period, having a negative and frequently destructive effect both on the condition of reservoir dams and their banks. This may be confirmed e.g. by a study by Wiatkowski et al. (2007), who reported that icing found on the Nowaki reservoir located in the Opolskie province in the winter of 2001/2002, caused titling of the middle pier of the footbridge leading to the sluice tower. As it was reported by Małecki (2008), hydrodynamic wave motion in the water table as a consequence of increased wind velocity combined with wetting, freezing and abrasion caused by floating ice also has a significant effect on concrete carbonatisation in the wave formation zone.

In turn, in the summer months a common problem in reservoir operation is related with the accumulation

of vegetation on damming structures, frequently reaching dams – particularly in period of high daily precipitation totals. Such a situation was observed in the second half of August 2017 on the dam of the Przebędowo reservoir. The jam caused by vegetation threatened with crest overspill and flooding of buildings located in the vicinity of the dam. Opening of bottom flood gates and the intervention of the fire brigade, who bent the bars away from the lateral walls of the dam, prevented the flooding event. Such actions, in the opinion of Nachlik (2006) may be classified as the so-called flood prevention measure, which promotes restoration or preservation of natural outflow conditions from the catchment. These are the actions, which facilitate limitation of flood damage in a given area and are frequently used in controlled retention facilities. According to Banach and Grobelska (2003), a common problem in the operation and use of dammed reservoirs is also connected with stability of their banks, which during their service life are frequently exposed to abrasion or accumulation processes.

As it was reported by Kundzewicz et al. (2010), systems regulating water relations to a considerable degree mitigate the effects of adverse weather phenomena; however, land reclamation, hydroengineering and flood control structures undergo progressive degradation. Due to negligence in this respect we more often eliminate the effects of extreme weather events rather than prevent the damage from occurring. For this reason, as it was stressed by Małecki and Pokładek (2010), in order to prevent structure failure and building disasters respective engineering inspection services need to perform continuous monitoring of dams (or any other damming structures) and evaluate the condition of these structures, including forecasting and estimating of structural changes occurring in these facilities and in their subsoil.

Apart from the above-mentioned problems related with the operation of dammed reservoirs a considerable problem is also connected with eutrophication. As it was reported by Pęczuła and Suchora (2011), susceptibility of dammed reservoirs to eutrophication depends on many factors, e.g. morphometry of their bowl, water exchange interval or land use prevalent in the catchment. According to Ławniczak (2016), excessive amounts of biogens may lead to an intensive growth of macrophytes limiting the operation capacity of reservoirs or abundant phytoplankton growth, particularly when leading to Cyanobacteria blooms. As it was stated by Dmitruk et al. (2013), dammed reservoirs are natural sedimentation sites for organic and mineral substances as well as pollutants transported by the river and discharged from the catchment, which frequently causes their rapid degradation and silting. The quantitative aspect of reservoir silting is closely related to the problem of bottom deposit contamination and its effect on the quality of water stored in the reservoirs.

Table 2 presents selected physico-chemical parameters of water in the Przebędowo reservoir and its inflow and outflow for selected months of the hydrologic year 2016. The Trojanka watercourse, on which the Przebędowo reservoir was constructed, is classified to natural watercourses code 17, i.e.

a sandy lowland stream, according to the Regulation of the Ministry of the Environment.

Analyses of water oxygenation showed differences within the monitoring points. Generally lower dissolved oxygen concentrations were recorded in the profile upstream of the reservoir (inflow). In turn, downstream of the reservoir these values were greater, while in April, May and August these waters were classified as purity class I.

In the discussed period from April to August water burden with organic pollutants affecting oxygen consumption in the self-purification process increased, as evidenced by the increasing values of Biochemical Oxygen Demand (BOD5). An increase in values of this index was consistent with the direction of water flow through the reservoir, while the highest value (12.4 mg O_2 per 1 l) was recorded in May. In the autumn period, both in September and October BOD5 values were lowest, amounting to 1 and 0.4 mg per 1 l, classifying waters to purity class I. Comparable results, particularly for spring and summer periods, were reported by Kanclerz et al. (2014) when analysing the effect of the Stare Miasto reservoir on water quality in the Powa river, in which those authors also emphasised greater dissolved oxygen levels and BOD5 in water downstream of the reservoir.

When analysing changes in concentrations of nitrates and nitrites it may generally be stated that in the Przebędowo reservoir in the investigated period the highest values of indexes, on average amounting to 9.0 and 0.18 $mg \cdot l^{-1}$, were recorded at the monitoring point located at the inflow, with these concentrations typically decreasing in the direction of water flow through the reservoir. Comparable results in relation to the above-mentioned indexes were recorded by Wiatkowski (2008) for the quality of water flowing into and out of the Młyny reservoir on the Julianpolka river.

It also needs to be stated here that nitrate concentrations in August and September both at the inflow, within the reservoir and at the outflow classified the water to purity class I. In contrast, in terms of nitrate concentrations in August, September and October water in the reservoir and at the outflow was of purity class II. Concentrations of phosphates at the analysed monitoring points showed no major fluctuations, with slightly higher values recorded in August and September at the outflow from the reservoir. However, throughout the entire analysed period waters at the three monitoring points were of purity class I. In turn, testing results for sulphates and electrolytic conductivity in that period classified waters at all the monitoring points outside purity class II.

It may be stated here that the agricultural character of land use in the direct catchment of the reservoir has a significant effect on water quality at the monitoring points. Particularly the elevated nitrate contents at the inflow to the reservoir indicate a considerable effect of land use in the adjacent areas, mainly in terms of fertilisation and the resulting runoff of biogens to the watercourse supplying the reservoir.

In studies conducted by Przybyła et al. (2014) and Sojka et al. (2017) concerning water quality in reservoirs, e.g. Jutrosin and Pakosław as well as Radzyny, those authors also stressed higher

TABLE 2. Chosen of water physicochemical indicators in the measurement-control points of the Przebędowo reservoir in chosen monts 2016 hydrological year

Location	Dissolved oxygen ($mg \cdot dm^{-3}$)	Biochemical oxygen demand, BOD5 ($mg \cdot dm^{-3}$)	Nitrates ($mg \cdot dm^{-3}$)	Nitrites ($mg \cdot dm^{-3}$)	Sulphates ($mg \cdot dm^{-3}$)	Phosphates ($mg \cdot dm^{-3}$)	Electrolytic conductivity ($\mu S \cdot cm^{-1}$)
12.04.2016							
Inflow	6	5.2	33.67	0.16	105.76	0.033	630
Reservoir	7.2	3.2	18.16	0.20	112.75	0.033	622
Outflow	12	11.2	15.06	0.23	116.04	0.033	610
05.05.2016							
Inflow	6.4	6	5.76	0.20	142.79	0.033	675
Reservoir	13.6	4.8	3.10	0.16	145.67	0.033	570
Outflow	12.8	12.4	2.22	0.10	131.68	0.033	586
17.08.2016							
Inflow	4.4	0.4	0.88	0.10	131.68	0.022	442
Reservoir	2	1.8	0.43	0	127.98	0.019	428
Outflow	6.8	6	0.88	0.03	129.62	0.042	447
20.09.2016							
Inflow	5.2	1.2	0.88	0.20	82.30	0.016	553
Reservoir	1.4	> 1.4	0	0.10	78.19	0.009	511
Outflow	4	1	0	0.07	92.18	0.042	565
10.10.2016							
Inflow	5.6	2.4	3.99	0.26	106.99	0.009	624
Reservoir	2.8	0.4	4.43	0.07	107.81	0.006	556
Outflow	6	0.4	3.99	0.07	93.82	0.022	541

contents of biogens in waters supplying the reservoir.

According to Jaguś and Rzętała (2009), it is the character of the catchment and water flowing into the reservoir in the form of watercourses or surface runoff that considerably affect variability in the quantitative and qualitative composition of the reservoir waters. In turn, as it was reported by Grochowska and Teodorowicz (2006), information on the natural resistance of the reservoir on the degradation and role served by the catchment in the acceleration or inhibition of its eutrophication is a key element in the protection of lake ecosystems, consisting in the limitation of runoff of biogenic and organic substances from the catchment.

According to Kanownik et al. (2011), at the accumulation of surface waters in reservoirs for their economic or recreation purposes, monitoring measures are required particularly in strongly anthropogenic suburban areas.

CONCLUSIONS

1. Within the framework of the small retention programme for the Wielkopolskie province in the years 2016–2030 it is planned to construct a total of 642 structures, within which approx. 184 million m^3 water may be stored. It needs to be stated here that the greater retention capacity in this province is provided by the construction of water reservoirs and lake damming. Only these two retention forms ensure storage of 170 million m^3 water, which accounts for 96% indicated retention capacity.

2. Apart from the positive aspects related with the use of water reservoirs, frequently within a year we face problems related with their operation. In the winter periods we observe the so-called icing, having a destructive effect both on the condition of reservoirs and on their banks. In contrast, in the summer periods common problems in the operation of reservoirs are caused by obstruction from vegetation accumulated on damming structures.

3. In the context of operation of retention reservoirs a typical problem is also related with their eutrophication strongly connected with influx of biogens. Analyses of selected water quality indicators in the Przebędowo reservoir showed, particularly in relation to nitrates and nitrites, their higher values at the inflow to the reservoir, indicating a considerable effect of land use in adjacent areas, mainly in terms of fertilisation and as a consequence runoff of biogens to the watercourse supplying the reservoir.

4. It may be stated that maintenance procedures performed twice a year as well as periodical inspection conducted once a year in view of the problems related with the operation of retention reservoirs seem insufficient.

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Streszczenie: *Ocena sposobu użytkowania wybranych zbiorników małej retencji na terenie województwa wielkopolskiego*. W pracy przedstawiono charakterystykę sześciu wybranych na obszarze województwa wielkopolskiego zbiorników małej retencji. Zlokalizowane w niedalekiej odległości od Poznania zbiorniki Radzyny oraz Przebędowo, usytuowany przy zachodniej granicy województwa zbiornik Miedzichowo, a także zbiorniki Stare Miasto oraz Jutrosin i Pakosław, które usytuowane są odpowiednio we wschodniej oraz w południowej części województwa. W pracy przedstawiono także wyniki badań dotyczące parametrów jakości wody w wybranym zbiorniku Przebędowo (na dopływie, w zbiorniku i odpływie) dla przykładowego 2016 roku. Największą powierzchnią zalewu wynoszącą około 110 ha i jednocześnie największą pojemnością (2,88 mln m^3) przy normalnym poziomie piętrzenia (NPP) charakteryzuje się oddany do realizacji w 2000 roku zbiornik Radzyny na rzece Samie, a najmniejszą powierzchnią zalewu (5,3 ha) oraz pojemnością (0,1 mln m^3) przy NPP charakteryzuje się zbiornik Miedzichowo, którego eksploatację zapoczątkowano w 2013 roku. Poza pozytywnymi aspektami funkcjonowania zbiorników retencyjnych często pojawiają się problemy związane z ich użytkowaniem i eksploatacją. W okresach zimowych dotyczy to główne tzw. zlodzeń, które negatywnie i często destrukcyjnie wpływają na stan zapór zbiorników oraz na ich brzegi. W miesiącach letnich często dużym problemem w eksploatacji zbiorników są zatory z roślinności na urządzeniach piętrzących, które często docierają do zapór, szczególnie w okresach charakteryzujących się dużymi sumami opadów dobowych.

Często pojawiającym się problemem w kontekście użytkowania zbiorników małej retencji jest również proces ich eutrofizacji silanie powiązany z dopływem substancji biogennych. Badania wybranych wskaźników jakości wody dla zbiornika Przebędowo wykazały, zwłaszcza w odniesieniu do azotanów i azotynów, ich większe wartości na dopływie do zbiornika, świadczące o dużym wpływie użytkowania terenów przyległych, głównie w odniesieniu do nawożenia, i w konsekwencji o spływach substancji biogennych do cieku zasilającego zbiornik.

Słowa kluczowe: gospodarka wodna, zbiorniki retencyjne, jakość wody

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