Using Reuse Water for Irrigation Green space of Naein City

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Abstract—Since water resources of desert Naein City are very limited, a approach which saves water resources and meanwhile meets the needs of the greenspace for water is to use city's sewage wastewater. Proper treatment of Naein's sewage up to the standards required for green space uses may solve some of the problems of green space development of the city. The present paper closely examines available statistics and information associated with city's sewage system, and determines complementary stages of sewage treatment facilities of the city. In the present paper, population, per capita water use, and required discharge for various greenspace pieces including different plants are calculated. Moreover, in order to facilitate the application of water resources, a Crude water distribution network apart from drinking water distribution network is designed, and a plan for mixing municipal wells' water with sewage wastewater in proposed mixing tanks is suggested. Hence, following greenspace irrigation reform and complementary plan, per capita greenspace of the city will be increased from current amount of 13.2 square meters to 32 square meters.

Keywords—Sewage Treatment Facility, Wastewater, Greenspace, Distribution Network, Naein City

I. INTRODUCTION

DUE to population growth, urban greenspace should be increased. This requires either providing more water resources or saving available water resources and planning to use sewage wastewater [1]. First executive directive of Iran's Energy Ministry regarding using sewage wastewater was developed in 2001 according to which regional Water Companies were required to consider treated sewage as part of the water resources managed by them and go on to plan for taking advantage of such resources.

Municipal sewage is mainly composed of household sewages including sewage produced in rest rooms, bathrooms, kitchens, etc. Throughout the country, main characteristics of such sewages are almost equal except the density which varies with per capita water use. In addition to abovementioned sources of sewage, the sewage produced in shops, repair centers, workshops and restaurants enter municipal sewerage system. Municipal sewage may constitute a nutritional source for plants and may be used for soil improvement [2].

Leibing was the first author to point out useful qualities of sewage and wastewater for greenspace irrigation. He recommended using such resources to irrigate farms, and today municipal sewage is used to irrigate greenspace in many cities around the world.

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For example, wastewater is used to irrigate the greenspace in California and the wastewater produce by a population of almost 7 million people is used in Germany to irrigate farms [3]. Torabian and Hashemain [1999], in addition to quantitative and qualitative examination of treated sewage in some of the regional sewage treatment facilities of Tehran, considered the possibility of using wastewaters to irrigate the greenspace and parks and stated that "according to guidelines set by World Health Advisor and regulations enforced by Environment Protection Advisor, treated wastewater may be used to irrigate the greenspace."[4] In developing countries, developing the application of sewage in farmlands has always served as a means of disposing of municipal sewage and providing water resources required for the greenspace. In Mexico, wastewater has been used for more than 100 years; in 1961, 120 to 300 million cubic meters of sewage had been used in this way [1]. Beijing sewage treatment facility everyday treats 300 thousand cubic meters of sewage to be used for irrigating farmlands and woods [1]. In Japan, reusing municipal sewage began in 1968 [5]. Hence, reusing urban wastewater may be a useful mechanism for areas having scarce water resources, especially in arid and semi-arid climates such as those of our country. This approach, however, needs close and careful consideration. It's worth noting that wastewater produced by Yazd City's sewage treatment facilities is used in non-desertification plans, developing regional green belts, etc [1].

According to published statistics and information, efficiency of irrigation of the greenspace in Iran is around 40%. [4] In order to improve efficiency and reduce wastes, separate Crude water distribution networks need be established in the city and state of the art methods of irrigation need be applied. Therefore, along with some other smaller cities of Iran, studies aimed at separating Crude water distribution network from drinking water distribution network are underway.

Naein County is located in the eastern part of Isfahan Province with Naein City as its center city. Average annual precipitation of the county is around 101.64 mms. January makes the coolest month of year with 3.7 degrees Celsius daytime temperature and July makes the warmest month of year with 28.7 degrees Celsius daytime temperature [6]. Climatic conditions of Naein City and the importance of water resources make it necessary for the city to take advantage of water resources in the most efficient way. Therefore, a whole body of studies was conducted to examine the use of municipal sewage wastewater and design a separate distribution network for it. The design includes main lines

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carrying sewage wastewater and wells' fresh water, appropriate storage facilities, and main and secondary lines of distribution network. In the proposed method, wastewater and wells' fresh water are first stored in storage facilities. Then, by applying proper pressure, the water is pumped into main and secondary lines of distribution network and finally delivered to the plant through gravity and pressure irrigation systems. It's predicted that with a proper management in place, irrigation efficiency will reach 60 to 85 percent in future.

II. CURRENT CONDITION OF GREENSPACE IN NAEIN CITY

In 2006, total greenspace of Naein City, including public greenspaces, parks and tree planted areas, was about 33.74 hectares and per capita greenspace was 13 square meters, much less than 20-25 square meters prescribed by environmental advisor to U.N.[7]

Problems associated with greenspace of Naein City include:

[1] Currently, gravity irrigation is used in more than 80% of Naein City's greenspace. Efficiency of this method is less than 50%. In addition, a good part of city's greenspace is irrigated by water tankers.

[2] Water resources evidently fail to meet the needs of the sector.

[3] In some cases, drinking water is used to irrigate greenspace.

[4] Lack of a separate water distribution network for the greenspace, and consequently lack of proper management, planning and use of available water resources.

III. GREENSPACE DEVELOPMENT PLAN

In our studies, the horizon of the plan set to be 2036 and the period is used for population analysis, predicting required discharge and analyzing hydraulic condition of the system. According to 2006 Public Census, the population of Naein City was 25,516 persons. Based on comprehensive plans and population analysis, population of Naein City will be around 36,000 persons in 2036 [7]. By using City's Comprehensive Plan and topography map, gross and net greenspace area of the city was calculated. According to above calculations, total net available and developable greenspace of the city is equal to 117.4 hectares.

IV. HYDROMODULE AND WATER DEMAND

Plant species adequate for the climate and soil of the region were determined for each quarter of the city based on their respective applications. By choosing appropriate irrigation system (dripping, sprinkler or surface irrigation) for each greenspace quarter, including squares, boulevards and trees planted along the roads, in the parks, jungle parks, cemeteries and sports pitches, irrigation module was calculated for each month of the year for every quarter. This formed the foundation of hydraulic calculations for greenspace water distribution lines. Maximum amount of average hydromodule belongs to July and is equal to 0.66 liter per second per hectare, and the maximum required discharge again belongs to July and is equal to 115 liter per second.

TABLE I
HYDROMODULE AND WATER DEMAND OF THE GREENSPACE OF NAEIN CITY

	March	April	May	June	July	August	September
Hydromodule (l/s/ha)	0.33	0.45	0.64	0.66	0.61	0.5	0.34
Discharge of Total Greenspace for 16 hourse (l/s)	56.85	78.1	112.62	115.05	105.8	87.9	59.7

	October	November	December	January	Februarys	Annual Average
Hydromodule (l/s/ha)	0.2	0.11	0.07	0.11	0.14	0.35
Discharge of Total Greenspace for 16 hourse (l/s)	34.5	19.8	12.3	19.5	24.2	60.50

V. EXAMINING AVAILABLE WATER RESOURCES

SEWAGE WASTEWATER

Every day, the volume of outgoing wastewater collected from 4 lagoons of sewerage system is about 3,600 cubic meters. Moreover, according to Urban Development Plan, this amount may be increased to 7,200 cubic meters per day [8]. Hence, current rate of sewage discharge is 41.5 liters per second, and will amount to 83 liters per second in future. Given current population of Naein City, the volume of produced sewage and predictions of future needs of the city in case of development, an outgoing discharge rate of 70.6 liters per second (as the peak) was considered the benchmark used in design efforts [2,9].

A. Wells

Table II lists Naein Municipality's wells to be used for greenspace irrigation [8].

TABLE II
CHARACTERISTICS OF MUNICIPALITY'S WELLS TO BE USED FOR GREENSPACE IRRIGATION

No.	Address	Depth (m)	Elv. (m)	Discharge (l/s)	Volume of Reservoir (cubic meters)
1	Imam Sq.	45	1581	4	
2	Laleh Sq.	45	1595	10	500
3	Mellat Park	45	1608	1	0
4	Nahalestan	45	1581	0.5	50
Sum				16	

B. Water Balance

Based on Development Plan of Naein City, maximum rate of wastewater discharge is calculated at 70.6 liter per second. Therefore, total production, i.e. wastewater discharge in addition to well's fresh water, amounts to 86.1 liter per second.

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Based on these calculations, and with regards to simultaneous irrigation of greenspace quarters in 1 and 3 day cycles, maximum rate of discharge consumption per day in peak month is 173.91 liter per second in a 16 hours period. Comparing above figures, we notice that surplus water should be stored for the peak time. Storage of water for 6 hours per day for a 3 day period will provide enough water to fully fill up city's storage facilities' capacity which is about 5,500 cubic meters. Current storage capacity of city is about 550 cubic meters and consists of two storage facilities, Laleh Park and Nahalestan Reservoir. Therefore, new storage facilities should have a capacity of about 5,000 cubic meters. For new facilities, two concrete ground tanks with the capacity of 3,500 and 1,500 cubic meters respectively are suggested. Locations of new storage facilities are shown on Map 1 and Map 2.

VI. EXAMINING IMPORTANT FACTORS OF NAEIN CITY'S SEWAGE

A. Biological Oxygen Demand (BOD5)

In order to determine BOD, we use BOD5 measure, i.e. biochemical oxygen demand in 5 days [11]. Naein City's sewage is a very dilute household sewage. In warm months of year, this factor is of higher values, and its maximum (63) belongs to spring.
BOD value suitable for greenspace application is 100 [4]. According to this standard, using Naein City's household sewage in greenspace applications is allowed.

B. Chemical Oxygen Demand (COD)

In this regards, the standard set by Iran's Environment Protection Advisor for greenspace applications is 200 mg/l. This factor is of higher values in warm months of year, and minimum and maximum values of COD are 150 (during winter) and 275 (during summer), respectively. Comparing COD values with relevant standards, due to higher value of the factor during spring and summer, application of Naein City's sewage in warm months of the year is troublesome.

C. Electrical Conductance (EC)

According to classification of irrigation water based on total soluble salts, hazard rate of irrigation waters is as follows: EC values between 0.1 and 0.25 reflect low hazard rate; EC values between 0.25 and 0.75 reflect average hazard rate; EC values between 0.75 and 2.25 reflect high hazard rate; and EC values above 2.25 reflect very high hazard rate [10]. Naein City's sewage is of a high hazard rate in all months. The value of EC is 1.5 and 2.4 in January and December, respectively.

D. Total Suspended Solids (TSS)

In terms of water's potential to block local irrigation systems (i.e. dripping irrigation), the Naein City's wastewater may be partially to averagely problematic [10]. According to FAO, maximum allowed value of TSS is 200 mg/l [12]. Examining TSS value of Naein City's sewage in 2008, the maximum value of TSS belongs to spring and summer. From spring to winter, TSS values are on a slippery slope. According to relevant standard of framing applications (100

mg/l), Naein City's sewage is problematic in October, November and during winter.

E. pH

The sewage output pH recommended by Iran's Environment Protection Advisor for greenspace and irrigation applications is 8.5 and 6, respectively [4]. According to National Committee of Irrigation and Drainage, for dripping irrigation, a pH value below 7 reflects unlimitedly proper quality, a pH value between 7 and 8 reflects limitedly proper quality, and a pH value above 8 reflects unlimitedly proper quality [10]. Based on those standards, sewage pH falls in the allowed range and may be used with no limit. According to qualitative classification of National Committee of Irrigation and Drainage, municipal sewage pH for irrigation applications is improper in March, October, December and February, and is averagely limited in other months. Minimum value of pH is 7.6 in November, and maximum value of pH is 8.4 in February.

F. Turbidity of Water

To measure turbidity of water, we may use Jackson Method [13]. As for Naein City's sewage, its turbidity level is above the standard throughout the year save winter. It's about 27 in winter and 100 in fall (the standard level is 50).

G. Number of Coliform

In most of the parts of the world, epidemics originate from sewage. Due to high number of coliforms and thermotolerant coliforms in Naein City's sewage, taking advantage of it in irrigation applications should be highly limited. The standard set for this factor is 1,000 and 400 coliforms per liter and thermotolerant coliforms per liter, respectively. However, as for Naein City's sewage during the winter, that factor is around 6,500 and 32,500 coliforms per liter and thermotolerant coliforms per liter, respectively. Sewage treatment methods may significantly reduce microbiological disease-causing agents.

H. Rare Earth Elements and Heavy Metals

Heavy metals include zinc, cobalt, chrome, cadmium, lead, copper and nickel. If the soil contains a high amount of rare earth elements and heavy metals, such elements will accumulate in plant tissues in undesirable densities and inhibit the growth [14].
Standard level of heavy metals present in the wastewater used for irrigation is prescribed by reliable guidelines, such as those of United States Environment Protection Agency (USEPA). Comparing heavy metals content of Naein City's sewage with abovementioned standards shows that the sewage may be unlimitedly used in irrigation applications.

VII. SEWAGE TREATMENT

Sewage treatment is supposed to provide treated sewage which is suitable for reuse and doesn't endanger public health. Typical treatment methods include following processes:

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[1] Basic Treatment
[2] Primary Treatment
[3] Secondary Treatment
[4] Tertiary Treatment
[5] Disinfection
[6] Storage of Treated Sewage

Primary treatment is aimed at separating the content of suspended organic and mineral matter in presedimentation pools. Secondary treatment is supposed to significantly reduce the amount of organic and suspended matter of the sewage. Tertiary treatment is used to reduce nitrogen and phosphorus content of the sewage. It's worth noting that as for the irrigation applications, tertiary treatment may not be required. And finally disinfection substantially reduces microbiological disease-causing agents.

In the following table, various treatment methods are compared in terms of pollution reduction, ease of application and maintenance, and required land and energy.

TABLE III
COMPARING VARIOUS METHODS OF SEWAGE TREATMENT

	Treatment Method	Package Plant	Conventional Activated sludge	Extended Aeration	Bacteria Bed	Oxidation Ditch	Aeration Lagoon	Usual Lagoon
Method Indices	BOD Removal	F	F	F	F	G	G	G
	FC Removal	P	P	F	P	G	G	G
	SS Removal	F	G	G	G	F	F	F
	Parasite Eggs Removal	P	F	P	P	F	F	G
	Viruses Removal	P	F	P	P	G	G	G
Economic Factors	Easy and Cheap Manufacturing	P	P	P	P	F	F	G
	Ease of Application	P	P	P	F	F	P	G
	Space Saving	G	G	G	G	G	F	P
	Energy Saving	P	P	P	F	P	P	G
	Cost of Sludge Disposal	P	F	F	F	P	F	G

FC: Coliform   SS: Suspended Matter   G: Good   F: Fair   P: Poor

Compared to other methods, Lagooning is more effective in removing hazardous microbiological factors. Hence, the sewage treated by this method doesn't require disinfection stage. International sources such as World Health Organization (WHO) confirm that Lagooning is the most suitable treatment mechanism to prepare renovated sewage for irrigation applications. Anaerobic Lagoon and Combined NonAerobic/Aerobic Lagoon may be used separately or in series, or in series with or in parallel with poolsator.

The treated sewage prepared by lagooning may be used in agricultural applications with no need for further consideration of possible hazardous materials or subsequent containments. For example, if the sewage is held in lagoons for 5 days, the

removal rate of polyviruses amounts to 99%. Following table lists treatment stages recommended by World Health Organization for agricultural, recreation and municipal applications.

TABLE IV
SUGGESTED TREATMENT METHODS TO MEET THE GIVEN HEALTH CRITERIA FOR WASTEWATER REUSE (WORLD HEALTH ORGANIZATION)

	Irrigation			Recreation		Industrial Reuse	Municipal Reuse	
	Crops not for direct human consumption	Crops eaten, cooked; fish culture	Crops eaten Crude	No contact	Contact		Non potable	Potable
Health Criteria (see below for explanation of symbols)	A+F	B+F or D+F	D+F	B	D+G	C or D	C	E
Primary Treatment	•••	•••	•••	•••	•••	•••	•••	•••
Secondary Treatment		•••	•••	•••	•••	•••	•••	•••
Sand Filtration or Equivalent Polishing Methods		•	•		•••	•	•••	••
Nitrification						•		•••
Denitrification								••
Chemical Clarification						•		••
Carbon Adsorption								••
Ion Exchange or Other Means of Removing Ions						•		••
Disinfection		•	•••	•	•••	•	•••	•••a

Health Criteria:
A   Freedom from gross solids; significant removal of parasite eggs.
B   As A, plus significant removal of bacteria.
C   As A, plus more effective removal of bacteria, plus some removal of viruses.
D   Not more than 100 coliform organisms per 100 ml in 80% of samples.
E   No fecal coliform organisms in 100 ml, plus no virus particles in 1000 ml, plus no toxic effects on man, and other drinking-water criteria.
F   No chemicals that lead to undesirable residues in crops or fish.
G   No chemicals that lead to irritation of mucous membranes and skin.
In order to meet given health criteria, processes marked ••• will be essential. In addition, one or more processes marked •• will also be essential, and further processes marked • may sometimes be required.
a: free chlorine after 1 hour.

Disease-causing agents can not be sufficiently removed by simply adding a chlorination unit because the required amount of chlorine varies with sewage and some disease-causing agents are resistant to usual levels of applied chlorine. On the other hand, even after chlorination, bacteria are able to grow and multiply. Therefore, removing disease-causing agents should be considered while choosing treatment method. Using advanced sewage treatment, we may achieve microbial standards set for disposal of and reusing sewage in non-dinking municipal application.

Filtration plays a significant role in nematode and parasite egg removal. For example, sand filtration of a water sample containing 6 parasite eggs per liter entirely removed parasite eggs. Final treatment of sewage should leave no more than 1 worm egg and 1,000 coliform per liter. With regards to heavy metal containment which is an important factor of sewage quality and needs be seriously controlled, Naein City's sewage is not problematic and its reuse is allowed. According to a

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study conducted by Dr. Najafi et al. in 2001 on the quality of outgoing wastewater of South Treatment Facility of Isfahan, after filtration stage, BOD and TSS content shrinks to less than 25 mg/lit. Moreover, filtration removes about 81% of nitrogen and more than 90% of biologic indices of the wastewater [15].

VIII. PREDICTING WASTEWATER PRODUCED BY NAEIN SEWAGE TREATMENT FACILITY

Population and per capita water use was calculated for Project horizon. Based on 118-3 standard, 80% of water supplied to households (save greenspace applications), public applications, industries and businesses turn into sewage. This factor is called Sewage multiplier. In addition, given sewage losses, Wastewater multiplier was estimated at around 80%.

TABLE V
PREDICTING POPULATION, PER CAPITA WATER USE AND WATER DEMAND OF NAEIN CITY FOR PROJECT HORIZON

Year	2006	2036
Population	25,516	36,001
Per Capita Water Use	239.25	249.15
Water Demand (lit/s)	70.7	103.8
Sewage Discharge (lit/s)	60.1	88.2
Produced Wastewater Discharge (lit/s)	48.0	70.6

IX. STRUCTURE OF MAIN CONVEYANCE NETWORK AND DISTRIBUTION NETWORK OF DRINKING WATER

In these studies, Crude water distribution network of Naein City, including main sewage conveyance networks for sewage wastewater, wells' water and main and secondary lines of distribution network, were modeled, optimized and designed.

Through polyethylene pipe with a diameter of 350 mm, sewage wastewater produced in Sewage Treatment Facility located 3 kilometers east of Naein is pumped to the conveyance network and transported to a proposed reservoir with the capacity of 3,500 cubic meters in Kachuye Park. Then, through polyethylene pipe with a diameter of 200 mm, some wastewater is supplied to 1,500 cubic meters reservoir in the West Naein, 5 kilometers away from Kachuye Park. Total discharge of Imam Well is pumped to Laleh Park reservoir with the capacity of 500 cubic meters. In addition, around 2 liters per second of Laleh Park well's discharge is pumped to this reservoir. Remaining discharge of Laleh Park well, about 8 liters per second, is transported to West Naein reservoir, 3.5 kilometers away from Laleh Park, through polyethylene pipe with a diameter of 110 mm.

Nahalestan Well's water, with a discharge of about 0.8 liters per second, meets the water demand of Nahalestan greenspace.

Mellat Park Well's water, with a discharge of about 1 liter per second, is allocated to the greenspace neighboring Mellat Park.

Crude water distribution network of Naein City is composed of polyethylene pipes with diameters ranging from 50 to 350 millimeters. The pressure of network is 6 atmospheres. Total length of network's pipes is 87,296 meters.

X. CONCLUSION

A. Examining sewage wastewater of Naein City and comparing it with various standards shows that for greenspace irrigation applications, its pH in some months falls in improper and limited level, and in other months falls within standard level. In terms of salinity, EC and TDS factors, the sewage's application should be highly limited. In terms of BOD, the sewage may be applied unlimitedly. With regards to COD, the sewage is problematic in some seasons. The sewage is highly contaminated in terms of microbial agents and its application in greenspace irrigation may cause severe transfer of disease-causing agents.

B. Treated sewage can provide a wastewater discharge of about 70 liters per second to be reused in greenspace applications. Given severe problems of Naein City in terms of water resources, installing even costly advanced treatment facilities in various sectors seems reasonable and economic. With regards to Naein City Treatment Facility, given items referred to in the present paper, sand filtration is needed in addition to primary and secondary treatment in order to prepare the wastewater for greenspace and non-drinking applications. Moreover, to inhibit algal and bacteria growth and multiplication, chlorination is needed.

C. An important advantage of establishing a Crude water distribution network separate from drinking water distribution network is that various qualities of water may be supplied for different applications. This not only reduces the costs but also helps us to use high quality water resources in the most efficient way.

D. With a separate Crude water distribution network in place, pressure irrigation systems may be used in order to improve irrigation efficiency to global standard levels.

E. With the designed network in place, proper pressure (25 to 40 mH2o) is available in more than half of the city. Moreover, if appropriate taps and valves be installed in the network, the pressure may be increased to 40-50 meters. Given the water demand of Fire Department (290 cubic meters in emergency cases) and the capacity of proposed storage facilities, the Fire Department's water demand may be conveniently met even in warm months of the year.

F. Given current greenspace area, comprehensive plan and population of Naein City, reforming irrigation system of the greenspace and associated water distribution network will allow to increase per capita greenspace of the city from available 13.2 square meters to 32 square meters.

On following two maps, location of storage facilities and main pipes of designed distribution network are shown. Moreover,

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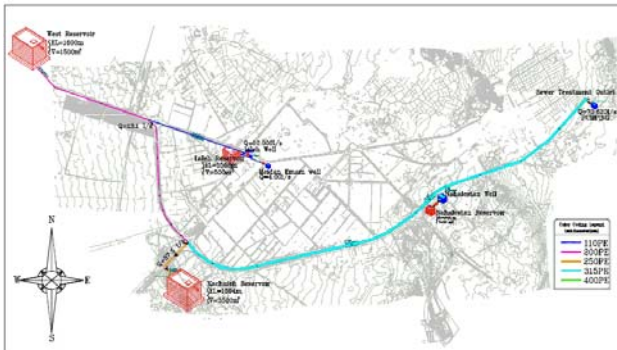Naein City's greenspace horizon is shown on Map 3.

Fig.1 proposed Conveyance pipelines for wastewater and wells' and storage facilities' Crude water.
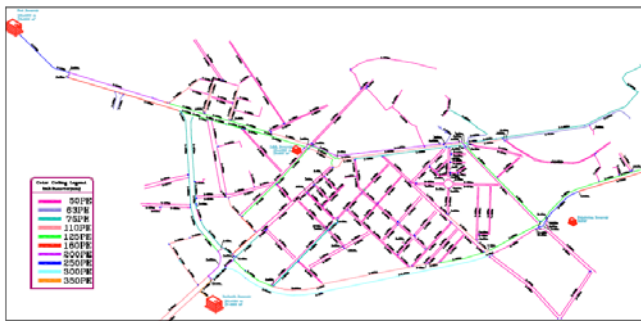

Fig. 2 Plan and type of main and secondary lines of designed Crude water distribution network

Fig. 3 Greenspace of Naein City in 2036 according to comprehensive plan of the city

10. ACKNOWLEDGEMENT

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