SPECIFICATION OF THE SANITARY BOUNDARIES OF A WELL

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ABSTRACT

The qualitative protection of the groundwater reservoirs that play a role in supplying drinking water of wells is one of the responsibilities and concerns of the people in charge of supplying and distributing drinking water such as water authority organizations and water and wastewater companies, nowadays.

In summary, sanitary boundaries of a well are the same as surface or subsurface areas around the well that supply well water during pumping. Contaminants can move and reach the water inside the well from this region.

Minimum Safety Distance (MSD) is defined as local conditions, the most important which are the geological and hydrological conditions, the quality of wastewater disposal in human communities and the number of sources of contamination present in the region. MSD is dependent on aquifers, soil layers, soil permeability, groundwater flow direction and velocity, concentration of pollutants, etc. Thus the specification of MSD that can be applied globally is very difficult for different areas.

Sanitary boundaries include contamination-exposed boundary (R_1), mandatory protection boundary (R_2) and protection boundary (R_3). In order to do this, the optimum and accurate calculation of boundaries using the scientific principles are of great importance because the calculation and application of the smaller boundary increases the risk of pollution and the application of the more extended boundary leads to the loss of budget.

With regard to the importance of water supplies as one of the causes of development and their exploitation for different operations and with attention to our country's climatic characteristics that is considered as one of the arid and semi-arid regions of the world, serious investigations and researches in this field are necessary .

Key Words : Sanitary boundary, Minimum Safety Distance, Qualitative protection

INTRODUCTION

The qualitative protection of the groundwater reservoirs that play a role in supplying drinking water of wells is one of the responsibilities and concerns of the people in charge of supplying and distributing drinking water such as water authority organizations and water and wastewater companies, nowadays[1].

Contamination of the ground waters is happened because of infiltration of various chemicals like detergents, oil products, toxic and waste materials, industries such as phenol, chromium, cyanide, etc. Cesspool and old wastewater collection systems are another source of the ground waters contamination. In these days, increasing scientific as well as industrial centers dealing with radioactive

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sources bring up the contamination risk of the depth aquifers[2].

Biological and chemical contaminants having organic and inorganic compounds in soluble, colloidal, and suspended forms can be infiltrated into the well up to a certain and limit distant depending upon soil formation. Bacteria have the least motion in the groundwater; colloidal particles and bacteria have even less movement comparing to the soluble materials and the soluble materials can move much more distance in the groundwater of a region[3].

MATERIAL AND METHODS

Boundary refers to a distance surrounding a well, which its water quantity and quality will be affected by the environmental conditions because of pumping. In hydrology, it is called "Cone of Depression" or Impression Radius.

If this boundary is related to the hydrological effects, it will be called Impression and protective boundary and if it is related to the interring contaminants and the contaminants impression, it will be referred as Sanitary Boundary. In the scientific references, sanitary boundary is also called as "Capture Zone", "Zone of Contribution (ZOC)" and "Wellhead Protection Area (WHPA)". The followings are some definitions for the Well Sanitary Boundary (WSB):

WSB is the same surface or subsurface area around the well, where feed well during pumping and the contaminants can move towards the well from this area and reach the well water.

WSB is a distance around the well, where in this radius the chemical and microbial contaminants can enter the well water.

Well pumping changes natural subsurface balance and brings about reducing groundwater level around the well. This effect appearing as the groundwater drawdown occurs in the capture zone and is called the depression cone. There is another zone around the well named Zone of Contribution involving all the zones contributing in the well feed. A part of the well Impression zone is within the contribution zone. If groundwater movement towards well is considered in a certain time, the contribution zone in feeding well water in this certain time is called transformation zone, where is, in fact, a part of the contribution zone[4,5].

Minimum Safety Distance

Minimum Safety Distance (MSD) is referred to the local conditions; the most important among them is the area geological and hydrological conditions, the method of wastewater disposal in human being communities, and the number of the existing contaminant sources in the area. Therefore, introducing feasible MSD at global level for different areas is a difficult task.

The MSD for a toilet in the area having remarkable permeable layers and laid over an unsaturated layer is much more far than the area having relatively thick, unsaturated with low permeability. In the areas with porous rock aquifers (in these aquifers water is impounded rack fractures) water velocity and, therefore, the contaminants movement velocity is more and it should be considered in determining MSD. Also, the groundwater flow direction in an area will affect the MSD. As a general rule, the groundwater flow direction in low depth (bore-well) wells reflects the ground surface topography and therefore, the contamination sources should be located in the downstream of the drinking water resources depending upon the area conditions.

The contamination concentration also makes effect on the MSD and it is important in the urban areas with low income and high density, where on-site sanitary toilets are used or in the areas where unconventional wastewater treatment exists. In most cases obtaining hydrological data in rural areas is very difficult and in community-based programs, it maybe infeasible to do individual survey and study for each area. However, specification of the MSD is carried out with less accuracy than other areas **(Fig.1)**. In order to specify suitable MSD, information about the pedology of the area is required and this involves excavation up to the groundwater level and precisely recording change in the soil texture and type of rocks, especially change in the grain size, permeability, compressibility, and the location of the saturation layers.

All of the wells must be supervised by the local authorities and boards. Upgrading the unprotected wells and building up new protected wells must be enhanced for the community. Most of the unprotected bore-wells have high level of fecal coliforms (min. 100 fecal coliforms per 100 ml of the water sample) unless sever and strict measurements is applied to assure lack of the contamination in such wells. Using hand pumps for discharging water from the well is suitable, since the minimum hand and environment contact with the interior of the well can occur and hence leads into less contamination. Disinfection (chlorination) is required in the case of contamination existence which necessitates adequate knowledge and experience.

Velocity of the groundwater flow varies in different areas and depends upon the soil permeability which is in the range of meter fraction per day; 0.02-0.25 m/day for sand; 50 m/day for very high permeable gravel and even higher velocity in the porous rocks like limestone. The MSD for the impermeable clay, therefore, it maybe less than few meters while it can exceed than 100 meters in sand. It can be up to several kilometers in the permeable gravel media or in the areas with porous low-depth aquifers. **Fig.1** shows different sources of the entry of the contaminants in the well boundary. In **Fig. 2**, a schematic representation of an improved deep-well is shown.

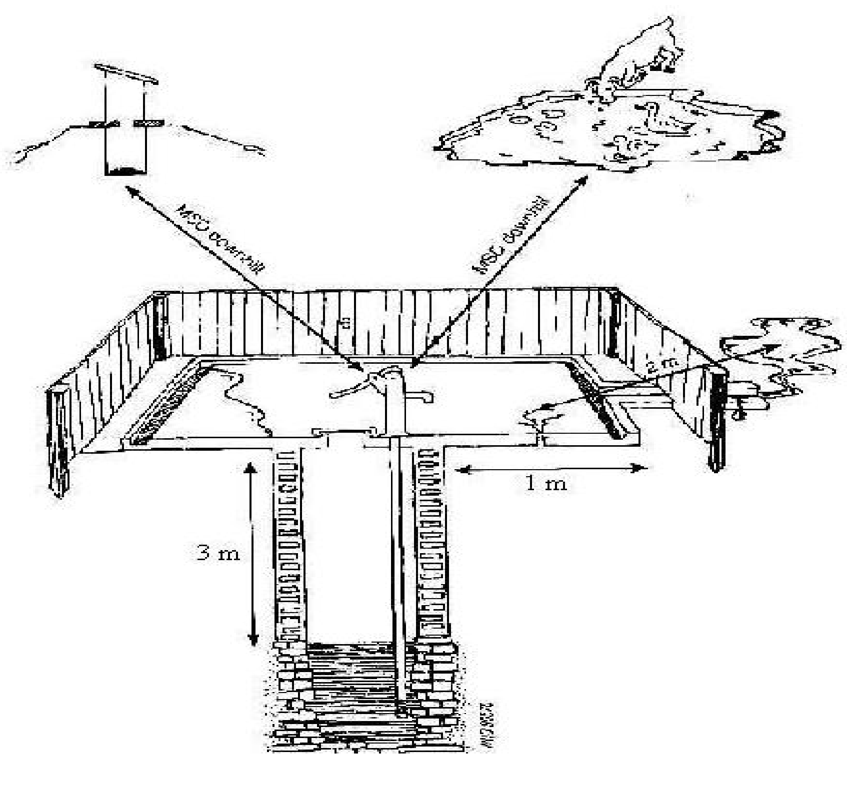

Fig. 1 : Sources of the contamination within the well boundary

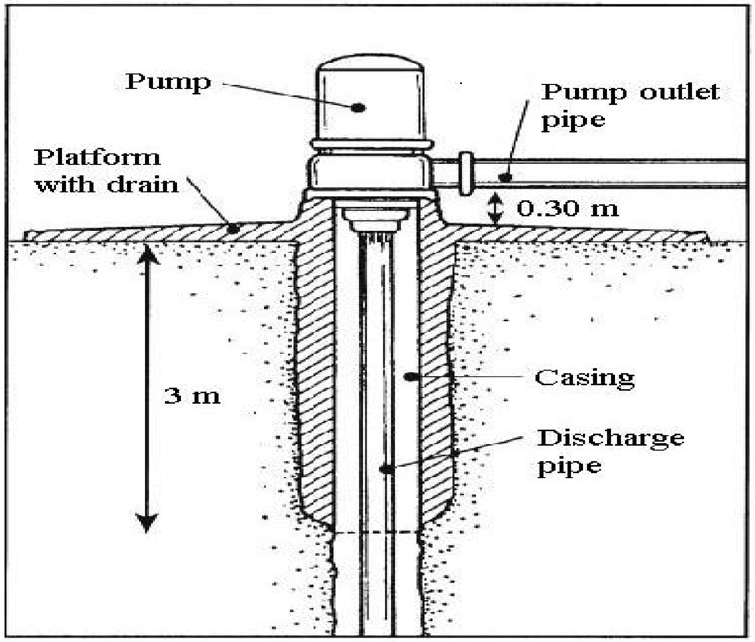

Fig. 2 : Schematic representation of an improved deep well

RESULTS AND DISCUSSION

Role of the Microorganisms in the Sanitary Boundary

For long centuries, presence of the pathogenic microorganisms in groundwater and conservation of the harvested drinking water from these resources had been and is one of the main concerns. Bacteria can survive for more than 6 months in the deep semi-saturated soil layers and if high concentration of oxygen exists in these layers. Pathogens can be destroyed after while in the soil because of the physical, biological and chemical factors. High temperature, pH≈7, low oxygen and high concentration of organic carbon in soil enhance removal rate of the pathogenic bacteria. Removal of the microbiological elements in soil and groundwater depends on these factors. For example, coliform removal is 99.9 % after less than 8 days while Escherichia needs 50 days to have this percentage removal.

Viruses can move in the relatively long depth and horizontal distances under the earth. For example, movement of the viruses in the depth of 67 m and horizontal movement for a distance of 408 m have been reported by some of the researchers. A lot of studies have been conducted on the effective factors in surveillance of the viruses in groundwater. These studies show that temperature is one of the important factors in this regard.

The studies have also indicated that viruses have more life time in well water than surface water and 0.1 % of the Poliovirus, Hepatitisvirus and Enterovirus can survive for more than 140 days in groundwater which is much more than the Escherichia bacteria ones. At the temperature below 150ºC, Poliovirus can exist for more than 250 days. Based on the researchers finding in the European countries, it is suggested that a lag time of 50-60 days and wherever be possible up to one year is considered for conservation of the well waters against viruses and pathogenic bacteria.

For example, a lag time of 50 days means it takes 50 days for the released viruses in the earth to move from a point around the well into the well before their death. In addition, a minimum 100 m radius distance around the well as the sanitary boundary zone has been recommended to conserve against viruses and bacteria. These recommendations are the result of the expanded studies of several years on the movement and surveillance of the viruses and bacteria in groundwater.

Types of the Sanitary Boundaries (Fig. 3)

1. Contamination-exposed boundary R_1

There is a radius around the water resource where contamination can easily enter to water. This boundary can be related to the microbial or chemical contamination. In this boundary, constructing any contamination sources such as domestic and industrial wastewater, solid waste disposal, building up animal husbandry, or industrial units, disposal of the toxins and oil materials should be strictly prevented. Since soil profile of a well does not have a uniform grain and uniform transmission coefficient of water, the minimum protective boundary is considered as 10-50 m from the center of the well. Also, more depletion of the pumping water table, farther boundary[6].

2. Mandatory protection Boundary R_2

Mandatory protection boundary or a limited area nearby the well where is at the risk of contamination. This boundary should be protected against the entrance of viruses, biological activity of the bacteria such as increasing ammonia nitrogen ($NH_4^+ >$ 1 mg/l), nitrite ($NO_2^- >$1 mg/l) and nirate ($NO_3^- >$1mg/l) phosphates concentration and detergents. Pathogenic bacteria will be destroyed in the groundwater after 50 days while coarse particles and parasite cysts are completely screened at the contamination-exposed boundary. From the health point of view, therefore, this boundary should be such specified that any water drop containing harmful bacteria take 50 days to enter the water resource from the contamination point. Bacteria will not survive after passing this time and water will lose disease prevalence. Calculation of this 50 days time is possible by determining real velocity of groundwater flow. As water velocity in the karst area is high (V_{max}=10-585 m/h), the mandatory protective boundary is great. Therefore, the required compulsory boundary is high, in the range of 12-600 km based on the 50 days life of the pathogenic bacteria.

$$R_2 min = 50d \times 24(d/h) \times 10(m/h) = 12000m = 12\,km$$

$$R_2 max = 50d \times 24(d/h) \times 585(m/h) = 602000m \approx 60\,km$$

While in alluvial wells, where the real velocity of the water flow (V_{max}) is low, less distance and using of probe systems of the radioactive materials, Uranin, Rodamin, salt, permissible dye and dye flavors are applicable[7,8].

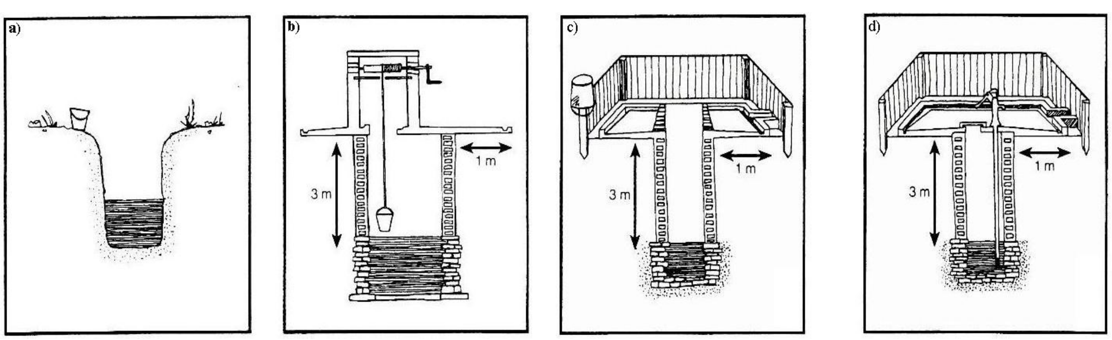

Fig. 3 : Schematic representations of the wells : (a). Dug well, (b). Dug well with wheel, (c). Uncovered dug well and (d). Improved well with back hand pump

1. Supporting Boundary R_3

Supporting boundary or a farther boundary than the other two boundaries, where there is a chance for contamination. This boundary is set against long-term contaminants, radioactive materials, heavy metals, nitrate, phosphate, and some of the toxins. This boundary is the same permeable boundary, which is also called as Contaminations Risk Boundary[9].

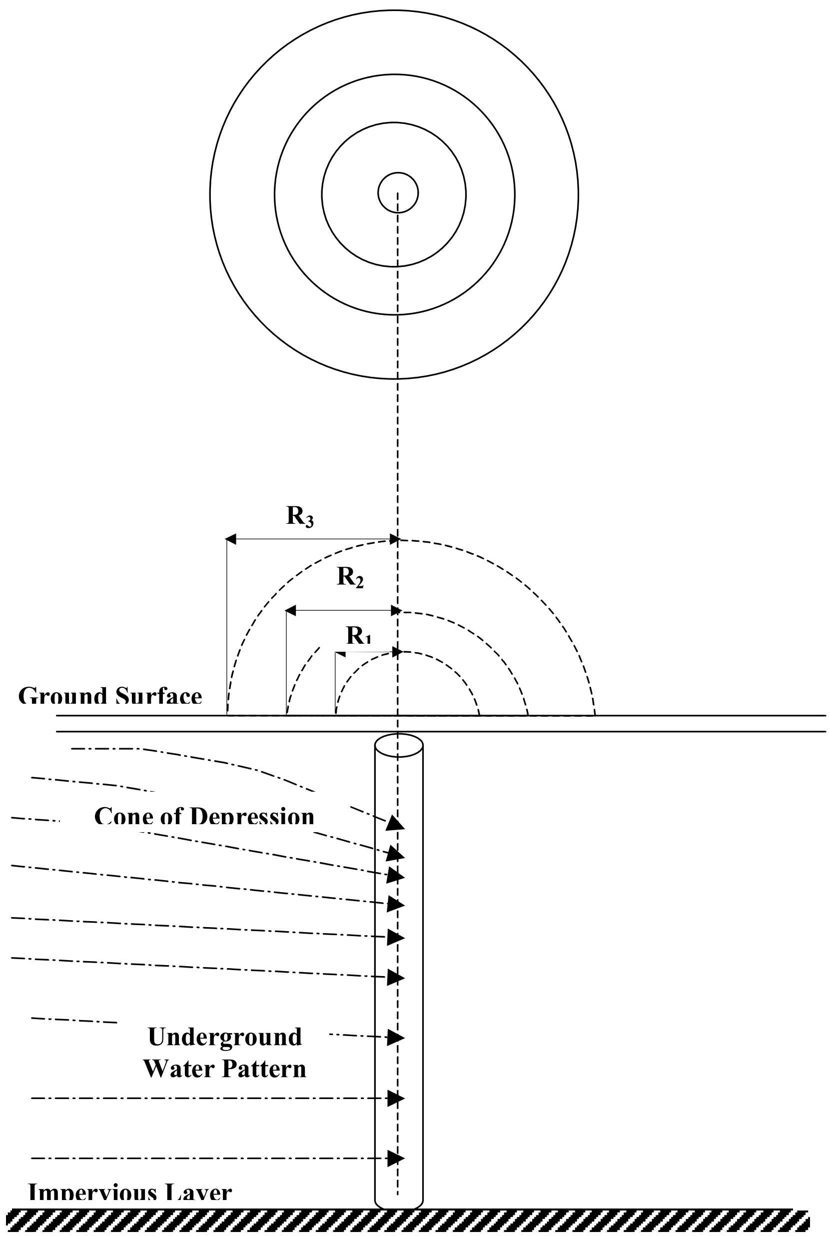

Fig. 4 : Hydraulic characteristics of different types of the sanitary boundaries

CONCLUSION

In this case, calculation of the optimum and precise boundaries using scientific principles has a great and particular importance, since calculation and applying smaller boundary increases contamination and vaster boundary brings about wasting investment. Because of the water importance as one of the development resources and its consumption for various applications and due to particular climatic characteristics of our country (Iran) that is considered as arid and semiarid areas of the world, serious study and researches is required in this regard. As all of the health goals is secured by the contamination risk or supporting boundary that is generally called sanitary boundary, it is considered. Because of the importance of the following sanitary boundaries of drinking water resources, the measures required in determining permissible or impermissible water resources are shown in table 1. In figure.4, a diagram of the Hydraulic characteristics of different types of the sanitary boundaries has been presented.

Sl. No.	Types of the contamination threatening measures	Different boundaries		
		R_1	R_2	R_3
1	Domestic wastewater, Radioactive material, Industrial and alkali wastewater	+[a]	+	+
2	Oil products, pipes and oil material tanks, untreated industrial sewers	+	+	+
3	Constructing towns without wastewater network, airport and army ammunition depot and military exercise yard, construction of the elevated buildings and towers, sports land and carwashes and gardens requiring fertilizer and poisoning and…	+	+	+
4	Building up oil and oil products tanks having 10m3 capacity, constructing building for radioactive material exploring, storage of the chemical fertilizers and quarries	+	+	+
5	Constructing cemetery, waste dumping, and parking	+	+	+
6	Withdrawal of sand and gravel, making pits and large depression	+	+	+
7	Farm making using whirlpool irrigation	+	-[b]	-

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